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[THIRD SERIES.]

ART. XXXVII.—*On the Wave Length of the D_3 Helium Line;* by A. DEFOREST PALMER, JR.

OWING to the recent increased interest in the wave length of the helium lines due to the discovery of terrestrial helium, I have been led to calculate some observations on the D_3 chromosphere line carried out by myself at the Physical Laboratory of the Johns Hopkins University during February and March, 1893.

The measurements were made on the large fixed telescope spectrometer, used by Dr. Louis Bell* in his determination of the absolute wave length of the D solar lines, with a plane speculum metal grating having about fourteen thousand lines to the inch and five inches of grating space. The telescopes of this instrument are $16{\cdot}4^{cm}$ clear aperture and about 2·5 meters focal length; and with the grating used I obtained good dispersion and excellent definition in the first spectrum to the right of the normal to the grating. All the observations were made in this spectrum on account of its superior definition.

An image of the sun about 1^{cm} in diameter was formed on the slit of the instrument by aid of a large Foucault heliostat, and an achromatic lens of about four inches aperture. Appliances were provided for moving the image laterally across the slit, and, by means of a total reflecting prism, for turning it about the direction of the beam as an axis to bring any desired point of the limb over the slit.

* This Journal, vol. xxxv, p. 265.

The D_3 line appeared only when the sun's image was tangent to the slit and then as a bright but very short line in the center of the field of view vertically considered. Its definition and intensity were found to vary greatly from day to day, and for different points on the sun's limb. In general, when a solar prominence lay across the slit the line was very broad and intense, but the definition of its edges was poor, thus rendering it impossible to set the cross hairs on it with accuracy. The best combination of intensity and definition was obtained by avoiding prominences and working only on very clear days.

The observations were made by the ordinary micrometric method, the D_3 line being compared with the best solar standard lines in the field of view. The wave lengths of these standard lines, as taken from Prof. Rowland's "Table of Standard Wave Lengths,"* were

Fe	5916·475	Fe	5862·580
Fe	5914·384	Fe	5859·810
Fe	5905·895	Ba	5853·903
Na. D_1	5896·154	Average value	5887·028

Seventeen series of measurements were made, in each of which equal numbers of observations were taken on diametrically opposite points of the sun's limb in order to eliminate the effect of rotation.

The wave length of D_3 was calculated from each of these series by Prof. Rowland's method of interpolation, on the assumption that, for the space used, the spectrum was essentially normal. The average of the seventeen values thus found gives

$$5875{\cdot}939 \pm {\cdot}006$$

for the wave length of the D_3 line, the probable error being calculated from the deviations of the several values from the mean in the usual manner.

To test the accuracy of the observations and method of calculation, the wave length of the mean line was computed from the observations and found to be 5887·027, a value which differs only by ·001 from the average of the wave lengths of the standard lines used, 5887·028.

I am indebted to Prof. H. A. Rowland and Dr. J. S. Ames for permission to use apparatus and for suggestions, and to Mr. W. S. Day for aid in making the observations.

Wilson Physical Laboratory, Brown University, Oct. 17, 1895.

* Astr. and Astro.-Phys., vol. xii, p. 321, and Phil. Mag., V, vol. xxxvi, p. 49.

ART. XXXVIII.—*Some additional Notes on Argon and Helium;* by EDWIN A. HILL.

AN English scientist in a recent letter, referring to the point made in my article on argon,* as to the inconsistency of regarding a free or nascent monatomic atom as devoid of chemical affinity, asks the very pertinent question whether I have considered the case of mercury vapor, which at 800° is monatomic and yet has practically no chemical affinity. I had indeed given this case some consideration, but lack of space kept me from referring to it in my previous article.

Lord Rayleigh and Prof. Ramsay, in their original memoir, use the following language: "In conclusion, it need excite no astonishment that argon is so indifferent to reagents. For mercury, although monatomic, forms compounds which are by no means stable at a high temperature in the gaseous state, and attempts to produce compounds of argon may be likened to attempts to cause combination between mercury gas at 800° and other elements." The assumption evidently being, that at all ordinary temperatures, argon is heated to a point above that at which chemical affinity is strongly manifested.

Of course argon may yet prove to be either a mixture or a compound of elements, but assuming it to be a single element, the important question still remains unsettled as to the number of atoms comprising its molecule.

The ratio of the two specific heats, as derived from experiments on the velocity of sound in argon, has been shown to be about 1·65, approximating closely to 1·67, the value which, according to the theory of Clausius, proves the gas to have no energy of rotation. The conclusion, that therefore the gas is monatomic, depends on at least three things:

1st. On the correctness of the assumption that a gas, with *little* or no rotational energy, cannot be di- or *n*-atomic, but must be monatomic. In my article on argon (l. c.) I have endeavored to show, that the amount of rotational energy acquired by gaseous molecules will depend on the relation between the repulsive forces acting during the encounter, and the attractive forces aggregating the atoms into a molecule; and that even if the rotational energy be but slight, di- or *n*-atomicity may be possible, and monatomicity does not therefore necessarily follow.

2d. The conclusion also depends upon the correctness of the deduction of Clausius, that a ratio of the two specific heats of 1·67 proves the gas to have no rotational energy. This is

* This Journal, May, 1895, p. 413.

questioned by C. E. Basevi (Nature, July 4, 1895, p. 221), who endeavors to show that the equation $\beta = \frac{2}{3}\frac{1}{\gamma-1}$ of Clausius should be written $\beta = 3k\,(\gamma-1)$, where $\beta =$ the number of atoms in the gaseous molecule. This latter equation he shows gives 2 for the value of β in argon, leading to the conclusion that argon is diatomic; the mathematical proof being given in full.

3d. The conclusion also depends upon the correctness of the method for calculating the ratio of the two specific heats. This ratio, it will be remembered, was obtained indirectly from the velocity of sound in argon gas, as determined by the "Kundt" dust figures. Dr. G. Johnstone Stoney,* in a paper read before the Royal Society, May 20, 1895, doubts the correctness of the method employed in this determination, and advances proof in support of the position that the ratio 1·65, thus determined, is not the true ratio of specific heats; and if so it is of course not yet shown that argon gas has no rotational energy, and the argument for its monatomicity fails.

4th. Moreover Prof. B. Brauner remarks:† "It has been shown most ably by Mendelèeff, that the argument derived from the relation of specific heats = 1·66 is not absolutely conclusive in favor of the monatomicity of the gases in question (argon and helium).‡ Practically the same point was made independently by myself in my previous article (l. c., pp. 409–410) and also foot note quoting Mendelèeff, whose remarks came to my notice after that article was in press.

Now all of these points may be well taken, or some may be sustained and others not, *but if any one of them is sustained the argument for monatomicity fails.* The fact is that monatomicity seems to most careful thinkers utterly inconsistent with the classification of Mendelèeff, as well as all the various modifications of it which have appeared from time to time. There seems to be a deep-seated feeling that something remains to be explained; that the general principles upon which Newlands, De Chancourtois, Mendelèeff, Meyer, and the host of others have based their classifications, are in the main correct; and that argon fails to find its place in these classifications because some of our preconceived notions of the molecule need to be modified; and hence the foregoing attempts. At any rate, such are the views which impelled me to publish my own article on argon and the periodic law.

* Nature, July 18, 1895, p. 286, and Proc. Roy. Soc., vol. lviii, p. 177. Nature gives an abstract only.

† Chemical News, June 7, 1895, p. 271.

‡ See Proc. Russian Chem. and Phys. Soc., March 2 (14), 1895; Nature, vol. li, p. 543, and Chemical News, July 12, 1895, p. 14.

Now the pertinency of the question about argon and mercury vapor is this. Every fact which seems to be against the theory of monatomicity increases the probability that some one or more of these various explanations of the apparent inconsistency between the specific heat ratio and the conclusions drawn from the Periodic Law, may be correct. These explanations have not all the certainty of geometrical demonstrations, and if the verdict on them is, for instance, "*very probable but not fully proven*," then every additional argument strengthens the probability.

Of course, by far the strongest argument against monatomicity is the Periodic Law, but what we are looking for, I take it, is additional evidence.

I have already remarked (l. c., p. 412–413) that the nascent or monatomic state of the element is, par excellence, that in which chemical affinity has its maximum development, and that all our chemical experience leads us to associate chemical affinity with the free and uncombined atom. Why then, if argon be monatomic, that is free and uncombined, has it no chemical affinity at ordinary temperatures?

Because (it is replied), at those temperatures it is already heated above the point at which chemical combination is possible, and as when we cool mercury vapor from 800° down towards the point at which it assumes the liquid state, it begins to exhibit chemical affinity, so were argon likewise cooled down towards the point at which it begins to liquefy (−189·6°), it also would probably exhibit chemical affinity. Now even were this true, the monatomicity of argon would not thereby be directly proven; we should merely have removed one great and almost insuperable objection against the monatomic theory. But on the other hand, if it be not true, then it would be very difficult, if not impossible, to still hold the monatomic theory. Unfortunately, thus far no experiments have been published showing whether or not argon, near the low temperature at which it becomes liquid, exhibits chemical affinity.* Were this shown to be so, the case for monatomicity would be thus far strengthened, in that a great objection to the theory would have been removed; but our present knowledge of the properties of argon does not lead us to expect the display of any such affinities, for the only approach to an argon compound thus far made has been effected by apparently increasing

* The suggestion that argon compounds will only be formed at low temperatures, which follows directly from the assumption as to argon being too hot to combine, was made in the Educational Times, April 1, 1895, p. 479, and by Mr. C. J. Reed, Chem. News, May 3, 1895, p. 213.

instead of decreasing the energy of the gas (combination with benzene).*

There are, however, some experiments which seem to point against the monatomic theory. Thus Lord Rayleigh remarks as follows:† "It has turned out that the gas possesses the same value of $\frac{PV}{T}$ as hydrogen, and that the value of this expression is not altered between $-90°$ and $+250°$ . . . . Argon therefore shows no signs of association on cooling nor of dissociation on heating." The inference is that like change of temperature would have no greater effect on its chemical affinity than on its state of molecular aggregation.

In the absence, however, of direct experiment to determine the point, we may pursue an indirect method. If we can, from the known properties of argon, determine the class of bodies to which it belongs and with which its greatest analogies are found, then whatever we can predicate of these bodies as a class, we can within reasonable limits predicate of argon also. If they, as a class, are at ordinary temperatures far below instead of above the point at which chemical affinity is overpowered by heat, then probably argon is likewise below rather than above that point; and if below, then the theory of its monatomicity has before it the very difficult task, of explaining away the lack of chemical affinity in the free atom of argon.‡

Of course if the molecule is di- or *n*-atomic, its chemical inertness, like that of N^2, is readily explained by the strength of the force aggregating the atoms in the molecule, which force opposes chemical affinity, since the force of affinity must first disintegrate the molecule before combination with other atoms can take place, that is, must first overcome the force of molecular aggregation.

In general we may say of molecules, that starting with the minimum of heat in a solid and inactive state, as they acquire heat energy they become successively liquid, gaseous, and are

* And I may add Berthelot's combination with carbon disulphide, and more recently, Prof. Ramsay's combination with incandescent carbon, Chem. News, Aug. 2, 1895, p. 51; in all which cases a large quantity of electrical energy is needed to bring about the combination.

† Nature, June 6, 1895. p 127.

‡ It may occur to some that should argon prove a mixture of gases, the argument fails, and as the evidence favors the mixture theory, the argument has but little weight. The conclusion, however, is incorrect. If argon is a mixture, its components are gases which resemble each other in chemical and physical properties so closely, that up to the present time no method of separating them has been discovered. Hence any inference as to the properties of this mixture, which we call argon, must apply with equal correctness to all constituents present in quantity. But if argon is a mixture, the apparent conflict with the periodic law may be explained by the presence of two gases, of different densities, but similar chemical and physical properties.

finally dissociated into atoms. The force of molecular aggregation is a maximum when heat energy is a minimum. With increase of temperature the force of aggregation between like atoms (as I and I for example) is finally weakened, so that in the liquid or gaseous state the affinity of unlike atoms for each other becomes the stronger force. At still higher temperatures, even these forces are overcome by the repulsive action of heat. We may say that heat overpowers the forces of aggregation (like with like) first, and those of chemical affinity (like with unlike) later and with more difficulty. Now mercury at 800° has reached this latter stage, and it is claimed that argon at ordinary temperatures is in the same condition.

The analogies of argon are evidently with such elements as H, N, O, F, and Cl, that is to say with the metalloids of low atomic weight and specific gravity, gaseous at ordinary temperatures, somewhat soluble in water, with very low melting and boiling points, and very difficult to reduce to the liquid and solid state; rather than with the metals, among which mercury must be grouped, characterized by high atomic weights and specific gravities, liquid or solid at ordinary temperatures, insoluble in water, with much higher melting and boiling points, and easily reduced to the liquid and solid state.

In endeavoring to draw conclusions as to the argon molecule, it would therefore seem less forced to reason from what we know of the former, the metalloids, which it closely resembles, rather than the latter class of bodies, the metals, with which it has but few analogies. We are thus led to regard argon as a body in which the atoms in the molecule (if di- or *n*-atomic) are very firmly bound together, like nitrogen for example, and in fact from whatever side we approach the question we are struck with certain marked analogies existing between these two elements. The inert character of nitrogen and its disinclination for direct combination with other substances, has always been regarded as proving the strength of the force aggregating its atoms into a molecule, rather than showing that the substance is monatomic, and at a temperature so high that it is above or near the point at which combination is no longer possible; and why not also in the case of its analogue, argon?

Of the five gaseous elements to which argon is most closely analogous, H, N, O, F, Cl, all are at all ordinary temperatures far below the point at which combinations with other elements are impossible, and why should it be thought that argon is in any way different from them and above instead of below that temperature?

Let us consider the following table:

	Metalloids					Metals	
H	N	O	F	A	Cl	Na	Hg
1	14	16	19	20	35·5	23	200
gas	gas	gas	gas	gas	gas	solid	liquid
colorless	colorless	colorless	greenish	colorless	greenish yellow	white	white
electro neg.	electro neg.	electro neg.	electro neg.	?	electro neg.	electro pos.	electro pos.
Sp. Gr. ?	·90	1·37	1·265	1·5	1·33	·98	13·6
M. P.	−214°		below −95°	−189·6	−102°	95·5°	−38·5
B. P. −243°	−194°	−182·7°		−187·	−33·6°	red heat	+357·25
At Vol	15·5	14·	15·5?	13·3	25·6	23·5	14·1

Evidently argon has the characteristics of a metalloid rather than of a metal.

Now of these bodies, F, Cl, and O at ordinary temperatures exhibit the strongest tendencies known for combination with other substances, and H and N, in the nascent state, are almost equally endowed with chemical energy, but this energy is masked so to speak, gradationally, by the force holding the atoms together in the molecule which acts against and in opposition to the force tending to cause chemical combination. This opposing force of aggregation, comparatively weak in F, is stronger in Cl and O, still stronger in H, very much stronger in N, and why not also, let us say, even stronger yet in argon; thus accounting for its chemical inertness.

Indeed, is there any good ground, reasoning from the known properties of these elements (if it be an element), for believing argon to be in such a different physical condition from the rest of them, as is implied in the assumption that it is too hot to combine with other elements?

The discoverers in their memoir have remarked, that "the chemical behavior of nitrogen is such as to suggest that its dissociated atoms would possess a high degree of activity, and that even though they might be formed in the first instance their life would probably be short." Could not this language with great propriety be applied to its analogue, argon, also?

The theory, upon which argon at ordinary temperatures is considered to be in the same physical condition as mercury at 800°, is probably somewhat as follows: Starting with the elements in the solid state at the absolute zero of temperature, and devoid of energy or tendency towards chemical combination with other bodies, as temperature increases they finally become liquid and then gaseous. The increasing affinity toward other bodies increases with liquefaction, and still more so when the elements are vaporized; finally the heat becomes sufficient to dissociate the molecules into free atoms, in which state the tendency towards chemical combination is at its maximum, because the opposing force of molecular aggregation is reduced to zero. From this point on, an increase in temperature decreases the affinity towards other substances, until finally we arrive at a temperature above which the repulsive

force of heat (if such an expression be permissible), renders all combination impossible; which is the physical condition in which argon, at ordinary temperatures, is by this theory assumed to be.

Chemical affinity, then (the tendency for instance of the molecules H^2 and Cl^2 to form 2HCl), is not a simple force, but rather the resultant of at least three other *atomic*, not molecular, forces, viz: the attraction between the atoms H and Cl, which is opposed by the attractions between H and H and Cl and Cl. In general

$$F = f - \frac{c+h}{2}$$

where F = the chemical affinity of chlorine for hydrogen
f = the attraction between the atoms H and Cl
c = " " " Cl " Cl
h = " " " H " H

The theory assumes f, c and h to decrease with a rise, and increase with a fall in temperature, but f more slowly than c and h. When $f = \frac{c+h}{2}$, $F = 0$. If temperature be reduced f increases more slowly than $\frac{c+h}{2}$, hence the forces of molecular aggregation c and h are stronger the lower the temperature, while F, the affinity for other molecules, has a negative value.

Per contra, if temperature be increased, f decreases more slowly than $\frac{c+h}{2}$, and when $\frac{c}{2} + \frac{h}{2} = 0$, f will have a positive value, and F will have its maximum value, that is $F = f$; the case corresponding to the point where heat has dissociated the molecules into nascent atoms. Or rather the maximum value of F will occur somewhere between the dissociation temperatures of Cl and H. When both molecules are dissociated, since $\frac{c}{2} + \frac{h}{2} = 0$, increase of temperature reduces F and where $F = 0$, which case, for mercury vapor, is reached at 800°, we reach the upper limit of chemical combination; that is, the kinetic energy of the molecule is too great to allow of its combining with other molecules.

The following might at first seem an objection to this theory, viz: that considering the molecule HCl, if temperature is reduced f, the force binding the atoms H and Cl into a molecule finally becomes less than $\frac{h+c}{2}$ hence reduction of temperature ought to produce decomposition of HCl, whereas nothing of the sort occurs.

The answer is this, before HCl can be dissociated into H and Cl so that H^2 and Cl^2 can be formed, we must first overcome the force of attraction between the molecules of HCl,

which, as temperature is reduced, increases until sufficient to unite the molecules into solid HCl. Hence although $\frac{h+c}{2}$ does become greater than f with reduction of temperature, the tendency towards dissociation is more than overcome by the increased force of aggregation between the HCl molecules.

Strictly this molecular force should be taken into account above, but I have omitted it to simplify the discussion. Compare here the following language of Dr. Möller: "Scientists have proved that chemical action entirely ceases even before so low a temperature (−273°) is reached . . . The form of motion which we call affinity between different molecules seems at that temperature to be wholly extinct, but the other form of motion, the affinity between homogeneous molecules and between the atoms of which they are formed, does not appear to be much impaired by the lowest temperature we can produce."*

In general then we may roughly outline the gamut of changes produced by increments of heat energy as follows:

1st. Absolute zero, no energy, maximum of force of aggregation, minimum of force of affinity, solid state.

2d. Liquid state, first marked indications of the force of affinity (though weakly displayed by some solids under great pressures or certain electrical conditions), reduced force of aggregation.

3d. Gaseous state, force of affinity stronger, of aggregation weaker.

4th. Temperature where dissociation begins.

5th. Temperature where dissociation is complete, and the force of aggregation completely overcome as between like atoms. Maximum of chemical affinity in fourth or fifth stage.

6th. Temperature at which the dissociated atom has no affinity for any other atoms, like or unlike.

Let us now consider the following table of melting and boiling points.

	Substance.	Melting Point.	Difference.		Boiling Point.
H^2	= Hydrogen			Metalloids Average difference, 34·3	−243
N^2	= Nitrogen	−214°	19·6°		−194·4
CO	= Carbonic oxide	−207·	17·0		−190·
A^n	= Argon	−189·6	2·6		−187
O^2	= Oxygen				−182
CH^4	= Methane	−185·8	21·8		−164
NO	= Nitric oxide	−167·	13·4		−153·6
Cl^2	= Chlorine	−102·	68·4		− 33·6
Br^2	= Bromine	− 7·2	66 2		+ 59·
I^2	= Iodine	+114	70·		+184
Hg	= Mercury	−38·5	395·5	Metals Average diff., 511·3	+357
Cd	= Cadmium	+320	450·0		+750
Zn	= Zinc	420°	530		abt. 950°
Mg	= Magnesium	abt. 600	large		at very high temperature
Li	= Lithium	180°	670		abt. 750
Na	= Sodium	95·5	large		at red heat
K	= Potassium	60	"		above red heat

* F. P. Möller in Cod Liver Oil and Chemistry, p. 452.

Many of the metals are volatile if at all at such high temperatures that they have not been accurately measured, but generally the difference between the melting and boiling points is very great for metals. Apparently the rule is that the metalloids have a small while the metals have a large difference between their melting and boiling points, that is, that those elements (metals) whose chemical affinity is overcome by a small degree of heat energy, have large differences between their boiling and melting points, but that those (metalloids) whose affinity is only masked by a large degree of heat energy, have small differences between these points.

Thus compare Hg and Cd and the other metals above with H, N, O, Cl, Br and I.

Now if mercury at 800° is devoid of affinity, then the difference between its melting point and boiling point (395°) is about the same as between its boiling point and its upper limit of chemical combination (443°). But in the case of the metalloids, the difference between the melting and boiling points is small 66° to 70° for the halogens, from 17° to 20° for nitrogen, methane and carbonic oxide, and 13·4° for nitric oxide; while in these cases the difference is very large between the boiling points and the upper limits of combination, (by which I mean the temperatures at which chemical affinity is no longer manifest,) and the disproportion between these differences tends to become greater as the element approximates more and more closely to the characters of the ideal metalloid. Thus iodine begins to dissociate at 700° and at 1500° the process is complete, so that the upper limit of combination must be above 1500°, and instead of a ratio of differences like that in mercury of 395° to 443° we should have instead the ratio of 70° to 1416°+. *Inequality of differences characterizes the metalloids, equality the metals.* Now if argon is a metalloid (and is it not one if an element?), ought it not also to have this inequality of differences, and to have its upper limit of combination at a very high rather than low temperature? But if this limit be very high, argon can not at ordinary temperatures be like mercury at 800°, that is too hot to combine with other elements.

Again, if, as is the case, the melting and boiling points of argon are very close to each other, ought we not to expect that its melting point and upper limit should be separated by an interval correspondingly great?

In Br and Cl the characteristics become less metallic than with I, and approach more nearly to those of the ideal metalloid; and we find that while the difference between the melting and boiling points is but little changed, the differences between the boiling points and the upper limits are very greatly

increased. The same is equally true of N, O and H. Why not also of argon? The characteristics of argon are preëminently non-metallic, the difference (2·6°) between its melting and boiling points is small, as it should be, and not large as in the case of metallic mercury (395·5°); hence the inference that like other metalloids its upper limit of combination is far removed from its boiling point, much farther so than in the case of mercury, that is, far above 800°. But we are asked to believe that it is even below the ordinary temperature of the laboratory. Everything, however, seems to me to point to the contrary conclusion, that argon, like hydrogen, nitrogen, oxygen, chlorine, bromine and the other non-metallic elements of its class, has a very high upper limit of combination, and not a low one like the metals; and hence that at ordinary temperatures it is no more above that limit than are oxygen and nitrogen, but that its chemical inertness is fully explained by assuming that the force binding together the atoms within the molecule is strong as in the case of nitrogen (and to a less degree in hydrogen), and that the contrary view is not justified by known facts.

And this brings us back to our starting point. If the inert character of argon is not due to heat, then how can it be monatomic and also devoid of affinity?

To quote from my previous article—"which is the more unique, a diatomic gas without rotational energy, or a free atom devoid of chemical affinity?" The presumption is at once strongly raised that it is not a monatomic gas but diatomic and chemically inert because the two atoms of the molecule are very strongly bound together, in fact too strongly for any ordinary chemical affinity to overcome the bond, and that perhaps after all there is some hitherto unsuspected weak link in the chain of reasoning supposed to prove its monatomicity, or, as was stated in the editorial in Nature (Feb. 7, 1895): "Till further evidence is forthcoming, a heavy strain is thrown on the link of the chain of argument which connects the ratio of the specific heats with the monatomicity of the gas." I have already pointed out that the conclusion as to monatomicity depends on the correctness of various assumptions which have already been called in question, viz: 1st, that when the rotational energy is small the gas must necessarily be monatomic; 2d, that the ratio of the two specific heats of 1·67 proves absence of rotational energy, and hence monatomicity, and 3d, that the method used for determining this ratio can give correct results. If any one of these propositions fails, monatomicity can hardly be sustained; and any evidence against monatomicity, like that we have been considering, even though not conclusive of itself, yet when construed with these three pro-

positions, already called in question, and with due consideration of the requirements of the periodic law, makes out a pretty strong case, to say the least; and yet even here the future may give us new facts and require us to modify our conclusions; and there is hardly one of the many who have written upon this question that feels like laying down the law dogmatically at the present time, certainly not myself.

Since the publication of my previous paper, a notable discovery, that of helium, has been made by Prof. Ramsay, and the new gas has turned out to be a body very closely analogous to argon. As noted by the discoverer, both bodies resist sparking with O in presence of caustic alkali, both are unaltered by red hot magnesium. In each case the velocity of sound in the gas indicates approximately the value 1·66 as the ratio of the two specific heats, and although opinion is divided, says Prof. Ramsay and his colleagues, on the precise significance of this ratio, it appears to be most probable that in all cases, as in that of mercury, it points to the monatomicity of the molecule.

In general, they say,* an increase in molecular weight is accompanied by a rise in the boiling point, whether in the case of compounds or of elements; and they argue that if argon possessed the atomic weight 20 and molecular weight 40 it is probable its boiling point would lie above that of chlorine instead of being −187° and below that of oxygen, as is actually the case. And this they consider points towards a molecular formula A^1 rather than A^2 and so corroborates the monatomic theory.

It would seem to me, however, as if this conclusion did not follow so plainly as assumed. I have thrown the data upon which the argument is based into tabular form:

Molecule	H^2	N^2	O^2	A^n	O^3	Cl^2	Br^2	I^2
Molecular weight,	2	28	32	40	48	71	158	254
Boiling point,	−243°·5	−194·4°	−182·7°	−187·0	−106°	−33·6°	+59°	+184°
Melting point,	?	−214°	?	−189·6	?	−102°	−7·2°	+114

Now whatever its atomic weight, the molecular weight of argon gas is 40, and if we argue anything at all from molecular weights we shall, I think, be led to place argon in the above table ($A^n = 40$) between $O^2 = 32$ and $O^3 = 48$, into which place its melting and boiling points (respectively −189·6° and −187·°) cause it to fit fairly well. True its boiling point is a little lower, about 4°, than oxygen, while apparently it should be higher. Perhaps later determinations of these points may clear up the anomaly, which is hardly greater than the limits of possible error (in certain directions), or perhaps oxygen, as indicated by the researches of Baly,† may turn out to be a compound and

* Journal Chem. Society, July, 1895.
† Chemical News, April 5, 1895, p. 169.

not a single element, as has been so long supposed; or argon may be a mixture. At any rate, if boiling point is to be raised by an increase in molecular weight I see no reason for expecting $A^2 = 40$ to have a higher boiling point than $Cl^2 = 71$; as the molecular weight is lower so also should be the boiling point, and to my mind the facts either prove nothing or else favor rather than oppose the diatomic theory. If the boiling point depends upon molecular rather than atomic weight, can the boiling point give us any help in determining the atomic weight and the number of atoms in the molecule?

Some additional light seems to be thrown upon the subject by the recently determined refraction equivalent of argon. Mr. R. M. Deeley,* in his paper on this subject, after showing "that the refraction equivalents of the elements vary periodically with much regularity," remarks as follows:

"If argon, like calcium, has an atomic weight of 40, we should expect its refraction equivalent to be also about 10. On the other hand, if its atomic weight be 20, and if it (argon) falls between fluorine and sodium, the refraction equivalent might be 3 or even smaller than that of fluorine (1·6), for between carbon (5 or 6) and aluminum (7·7) the refraction equivalents decrease rapidly until fluorine is reached. They then increase with increasing atomic weight, and more than regain their original value at aluminum. The refraction equivalent is calculated from $P \times \frac{\mu-1}{d}$" (P = atomic weight, d = density, water taken as unity.)

Now Lord Rayleigh† has recently shown that for argon $\mu = 1{\cdot}000281$. This value is certainly remarkable, and proves argon to be as anomalous in its action upon the waves of light as in its behavior as to specific heats. In spite of its greater density (about 1·38, air = 1·) its refraction is only ·961 that of air; whereas, refraction usually increases with the density of the refracting medium instead of decreasing.

If $A' = 40$ the refraction equivalent by the above formula becomes about 6·3 instead of 10, the value which Mr. Deeley says would be required, were it monatomic with an atomic weight of 40; but if $A^2 = 40$ whence $A = 20$ (the diatomic theory) the corresponding value of the refraction equivalent 3·14 is entirely consistent with the position of argon in Mendelèeff's classification in Group VIII between fluorine = 1·6 and sodium = 4·3, 3·14 being very nearly a mean between these values; and as Mr. Deeley remarks (l. c.) "the equivalents decrease rapidly until fluorine is reached, and then increase with increasing atomic weight."

* See Chem. News, Feb. 8, 1895, p. 75.
† Nature, July 25, page 293.

The refraction equivalent of nitrogen as given by Mr. Deeley is 4·1 and on the theory (which has many who seem to favor it) that argon is an allotropic form of nitrogen with formula N^3, the corresponding value of the equivalent would be about 2·2 as against 4·1 required, so that this theory does not seem to be sustained. Assuming that the ratio 1·65 has been correctly determined, notwithstanding the criticism of Dr. Stoney, then the anomalous value of the rotational energy (disregarding the questions raised by Col. Basevi) seems to be associated in argon with an equally anomalous value of its refraction equivalent, and the question at once arises whether there is any connection between them.

Nature (July 18, 1895, p. 278), in discussing Mr. C. J. Reed's classification of the elements, makes a somewhat plausible suggestion worthy of consideration should the theory of monatomicity be sustained. "It is remarkable," says the editor, "that if helium has the atomic weight 4 it falls naturally in this group" (viz: $\frac{He}{4}$ 16 $\frac{?}{20}$ 16 $\frac{A}{36}$ 20 $\frac{Fe}{56}$ 28 $\frac{2}{84}$ 20 $\frac{Ro}{104}$ 28 $\frac{?}{132}$, all of which elements, if existent, can be classed as belonging in Family VIII), "and that its atomic weight deduced from the observed density, is somewhat greater than this number. If this difference should be due to the presence of some small quantity of element 84, then the spectroscopic evidence leading to the conclusion that argon and helium contain a common constituent would be explained." This theory assumes the monatomicity of both gases but places A = 36 between Cl = 35·5 and K = 39, which position is in no way inconsistent with the periodic law.

Thus density of helium = 2·13 and ×2 = 4·26 instead of 4.
" " argon = 19·9 and ×2 = 39·8 " 36.

The excessive densities being due to presence of the heavier element 84.*

I also have worked for some years on a classification of the elements, but like many others who have worked along similar lines I have been withheld from publication owing to the uncertainty surrounding the atomic weight determinations, the evidences that there were yet many undiscovered elements unknown to science, and the feeling that in such work, where the tendency to stray away into mere numerical speculation was very great, and where error was so likely to occur from the use of unreliable and imperfect data, the time was not yet fully ripe, and that the case was one where it was best to make haste very slowly.

* That helium is a mixture of several gases is now pretty well settled, and there is some evidence that argon is a mixture also, but not as conclusive.

We seem now, however, to be approaching an era of greater light, and I fully believe that the next few years will be productive of great advances in chemical and physical knowledge. I cannot now go into the subject of classification, but I will in conclusion refer to a closely related subject. In my previous article it will be remembered I called attention to a very regular alternation of intervals of 3 and 1 in the natural series of the elements, and in the table at page 416 of the May number of this Journal will be found a number of terms of the series so formed, not corresponding to known elements, which may possibly represent elements as yet unknown. It is remarkable that so many of those who have been giving their attention to the intricate subject of chemical classification have, by entirely different processes of reasoning, arrived independently at the common conclusion; that there are still a number of undiscovered elements, particularly in what may be termed the eighth or transitional family of Mendelèeff; and furthermore that they have so closely agreed on the atomic weights of the same. Of the various classifications thus far cited in connection with the discoveries of argon and helium, perhaps the most mature are those of Mr. C. J. Reed and M. Lecoq de Boisbaudran. When several investigators, working thus independently, and from data which though at times overlapping so to speak, yet are in the main different, or at any rate lead to different theories and systems of classification; when I say, in such cases, practically the same conclusions are arrived at, these results should naturally command a respectful consideration; and that is precisely what seems to have happened in the present case.

I can bring this out most clearly, I think, in tabular form, comparing some of the terms of the series referred to with the elements predicted by other classifications, etc.

1	2	3	4	5	6	7	8	9
Edwin A. Hill.	Lecoq. de Boisbaudran and B. Brauner.	C. J. Reed.	Dr. J. H. Gladstone.	Lt. Col. Sedgewick.	R. M. Deeley.	Prof. J. Emerson Reynolds.	Prof Ramsay and colleagues.	Julius Thomsen.
? = 3	2·9							
helium ? = 4	3·9	4		5	5		4·26	4
argon = 20	20·0945	20	20	20	20	20		20
? = 36	36·40 ± ·08	36		37	36	36 to 39	A=40 ?	36
? = 67		68		62				
? = 83	84·01 ± ·20	84		82	83		82	84
? = 116		116				*Note A*		
? = 131	132·71 ± ·15	132		129–130				132

Authorities.

1. Argon, Prouts' Hypothesis and the Periodic Law, this Journal, May, 1895, p. 416.
2. Chemical News. March 8, 1895, p. 116, and June 7, 1895, p. 271, and Jour. Chem. Soc, July. 1895, cccxcii. p. 550.
3. Ibid., May 3, 1895, p 213; Journal of the Franklin Institute, July, 1895, p. 68, and Nature, July 18, 1895, p. 278.
4. Nature, Feb. 21, 1895, p. 389.
5. Chemical News. March 22, 1895, p. 139.
6. Ibid., May 17, 1895, p. 244.
7. Nature, March 21, 1895, p. 486.
8. Journal Chemical Society, July, 1895, p. 707.
9. Zeit. Anorg. Chemie, viii, 283-8, and Chemisches Central-Blatt, Band II, 1895, p. 429.

Note A. Prof. Reynolds, while indicating the existence of members of Family VIII of higher weight than 36–39, does not assign their atomic weights in the article quoted. Atomic weights are given in the body of the table and the agreement, it will be seen, is very striking. It will be noted that three of the values in Mr. Reed's classification (68, 84, and 132) are just one unit greater than the corresponding values in my own series (67, 83 and 131).

The coincidences are certainly very striking.

New Haven, Ct., Aug. 10, 1895.

Addendum, October 7th, 1895.

The publication of the foregoing article having been delayed until the November issue renders necessary some additional remarks.

Prof. Ramsay (Chem. News, Aug. 2, 1895, p. 51) has produced a compound of carbon and argon by the action of an incandescent carbon arc in an atmosphere of argon. Four hours' action increased the volume one-fifth. Mr. Crookes (Chem. News, Aug. 30, 1895, p. 99) examined the product spectroscopically, finding residual argon, and also a compound with a spectrum very analogous to that of cyanogen and other carbon compounds. This, however, he says, is not evidence favoring the N^3 theory, since most volatile carbon compounds have similar spectra.

In view of the many analogies between argon and nitrogen, this new compound may have the formula CA, and be analogous to cyanogen, which can be formed in a very similar manner; i. e., by passing induction sparks between carbon poles in an atmosphere of nitrogen. This new compound furnishes a strong argument against the theory that argon at ordinary temperatures is like mercury at 800°, too hot to combine (hence its inertness). All the argon compounds thus far formed, as those of Berthelot with benzene and carbon disulphide, and the apparent absorption of argon by the magnesium and platinum poles, have been produced by heating and not cooling argon, and by increasing, not decreasing, its store of energy.

Lord Rayleigh, in his lecture before the Royal Institution (Nature, lii, 159–164) refers to the tendency of ozone O^3 to go slowly back to O^2, the normal type. But Bedson and Shaw (Chem. News, July 26, 1895, p. 48) have shown that the nitrogen contained in the natural crystals of rock salt contains the same proportion of argon as does atmospheric nitrogen, so that in a period of perhaps thousands of years there has been no tendency for argon to become N^2, hence the inference that argon is not N^3. Schild has pointed out (Chem. News, May 31, 1894, p. 259) that if argon is N^3, then any argon compound, when decomposed, should yield nitrogen, the normal, instead of argon, the allotropic form. Now Berthelot has shown (Chem. News, July 5, 1895, p. 1) that the analysis of the resinous compound of argon and carbon disulphide yields argon, not nitrogen, which makes strongly against the N^3 theory.

In line with this are the experiments of Peratoner and Oddo, mentioned by Meldola (Pres. Address, Nature Sept. 12, 1893, p. 483). They recently obtained nitrogen, not argon, from the electrolysis of hydrazoic acid and its salts, and they conclude that an allotropic form of nitrogen is impossible.

Is argon a mixture?

Evidence grows stronger that it is; as to helium there is not much doubt, and if anything can be argued from the analogies between argon and helium, argon is a mixture likewise.

Says Prof. Ramsay (Nature, July 25, 1895, p. 333): At least two helium lines are coincident with one each of two pairs of characteristic argon lines, but not with equal brilliancy, a faint argon line being identical with a prominent red helium line, and a strong red argon line with a faint red helium line; and besides these two there is a line in the orange red, faint in helium, but moderately strong in argon, which is very close if not identical.

Kayser's recent measurements of the argon lines (Chem. News, Aug. 30, p. 99), though measured to one more decimal place, do not agree with those of Crookes. They may not be to the same scale, but Mr. Crookes found 26 lines common to both the red and the blue argon spectra, whereas Kayser states they have no lines in common so far as he can see. This seems to favor the view that the red and blue argon spectra denote different constituents in the gas.

Helium proves much more insoluble in water than argon (1 vol. of water dissolves only ·0073 of helium). It has been found by Kayser associated with argon in the gases of certain mineral springs in Germany, and has also been by him detected in the atmosphere. (Chem News, Aug. 23, 1895, p. 89.) Also by Ch. Bouchard, associated with argon and some other

unknown gas in the gases of certain mineral springs in the Pyrenees mountains (Nature, Sept. 12, 1895, p, 487). The question raised as to the presence in cleveite gas of helium, the element giving the solar line D^3, has now been fully settled, the line being double both in solar and terrestrial helium. A good account of this question and its solution will be found in the Observatory for Aug. 1895, p. 295.

The work of Runge and Paschen upon the spectrum of cleveite gas subdivides the lines into two series, each of which in all probability stands for a different gas or class of gases. They also note certain rythmical relations between the wave lengths and those of hydrogen lines, and note a marked similarity in type between the helium lines and those of the spectra of the alkali metals. (Philosophical Magazine, Sept. 1895, p. 297.)

We come finally to the work of Mr. Crookes on the helium spectrum published in the last issue of the Journal, which may be summarized as follows, the grouping being my own:

HELIUM LINES OBSERVED BY WM. CROOKES, F.R.S., ETC.

Groups.	No. of Lines.	Intensities.			Occurrence in				
		Maximum.	Minimum.	Average.	Uraninite R.	Cleveite R.	Bröggerite R.	Bröggerite L.	Helium Puris.
A	16	30	4	9·2	strong	strong	strong	strong	strong
B	2	10	6	8	strong	strong		strong	strong
C	1	7	7	7	faint	strong		strong	strong
D	1	10	10	10	very faint	very faint		strong	strong
E	1	7	7	7	strong		strong	strong	strong
F	1	10	10	10		strong	strong		strong
G	1	5	5	5			strong	strong	strong
H	3	9	9	9	prominent	very faint		very faint	
h	1	8	8	8	prominent		very faint	very faint	
I	2	10	9	9·5	strong	strong			
J	1	8	8	8				strong	strong
K	1	4	4	4	strong				strong
L	1	10	10	10	very strong	very faint			
M	21	10	3	7·08	strong				
N	18	9	2	5·33					strong
Total	71				11	8	5	9	10

Blank spaces indicate the absence of lines and the table does not include a number of lines for which Crookes in his table gives no data, as for instance 4931·9 intensity 3, 4544·1 int. 5,

etc. The term strong above means that each line is equally strong in the minerals named; thus in Group B, one of the lines has intensity 8 and the other intensity 10, in all samples of the gas except bröggerite R.

The natural inference is that each of the groups A to N represents one or more distinct gases, except that *h* may after all be identical with H. The line D^3 occurs in Group A. Helium purissimum is apparently one of the most complex, and bröggerite R one of the most simple of the five gases. By construing the work of other observers, as Runge and Paschen, with that of Crookes, these groups may be still further subdivided. Apparently the gases given off by minerals of the uraninite type, which are loosely spoken of as helium while they contain helium, are very complex mixtures of gases of the argon and helium types containing anywhere from 4 or 5 to 11 or more distinct constituents.

Art. XXXIX.—*Recent Progress in Optics;** by W. LeConte Stevens. Part II.

Color Photography.

The conditions being now specified under which stationary light waves are produced, let us imagine common instead of monochromatic light, to be transmitted normally through a transparent sensitive film. Then a variety of stationary interference planes are produced. This is the underlying principle of the process employed by Lippmann in Paris, who in 1892† succeeded in obtaining a photograph of the solar spectrum in natural colors. Upon a surface backed with a reflecting mirror of mercury is a silver bromide albumen film, which has been treated with one or more aniline dyes to render it equally sensitive to waves of long and short period. After exposure and development the natural colors are manifested with brilliancy. Apart from the fundamental principle already expressed, it can scarcely be said that the rationale of the process has yet been very fully and clearly explained. Lippmann recognizes the stationary wave systems, with maxima and minima of brightness in the film and corresponding maxima and minima of silver deposit. If the incident light is homogeneous, a series of equidistant parallel planes of equal photographic efficiency are produced in the film. If the plate after development is illuminated with white light, then to every point within the film there comes from below a certain amount of reflected energy which is a continuous periodic function of its distance from the reflecting surface. The total reflected light of any color becomes then represented by the integral of this periodic function for the entire thickness of the layer. The solution of this integral brings the result that the intensity of the reflected light decreases with increasing thickness of the layer, approaching zero as a limit, so long as this light is of different wave length from the homogeneous light employed for illumination of the plate. Only light of the same wave length, or of an entire multiple of this, maintains a finite value. A similar consideration applies to each of the hues composing the white light. By such mathematical considerations Lippmann‡ reaches the conclusion that the light reflected from the plate must have exactly the same relations of wave length as that with which the plate was illuminated.

* Address delivered by the Vice-President of Section B at the meeting of the American Association for the Advancement of Science, August 29.

† Comptes Rendus, cxiv, p. 961, and cxv, p. 575.

‡ Journal de Physique, 1894, p. 97.

For the Lippmann photographs, which at first required a very long exposure and could even then be satisfactorily viewed at only a single definite angle, it is now claimed that an exposure of only a few seconds is needed, and that the colors are visible at all angles of incidence so long as the plate is moist.* But like the daguerreotypes of fifty years ago they are incapable of multiplication, and great as is the scientific interest connected with them, it seems scarcely probable that they can long continue to hold an important place practically. The problem of ascertaining definitely the cause of the return of a color the same as that which falls upon a given surface may seem to be solved mathematically, but the mastery of the physical conditions required to produce a single colored negative, from which may be had any desired number of positives with varied hues accurately reproduced, is still in the future. From the very nature of stationary light waves it does not appear probable that the Becquerel method as improved by Lippmann will give the means of multiplying copies of a single picture. Wiener has lately published an elaborate research upon this subject,† in which he recognizes the necessity for the employment not of interference colors but rather of what he calls body colors (körperfarben) due to chemical modification of the reflecting surface. M. Carey Lea‡ in 1887 obtained a rose-colored form of silver "photochloride" which "in the violet of the spectrum assumed a pure violet color, in the blue it acquired a slate blue, in green and yellow a bleaching influence was shown, in the red it remained unchanged." But in the absence of any means of fixing these colors a promising prospect brings disappointment.

While it is abundantly possible that colored illumination upon suitable color-receptive materials can give rise to similar body colors, we are still far from having these materials under control. There seems at present to be greater promise in another and quite different application of optical principles. The suggestion appears to have first been made by Maxwell§ in 1861, that photography in colors would be possible if sensitizing substances were discovered, each sensitive to only a single primary color. Three negatives might be obtained, one in each color; and three complementary positives from these, when superposed and carefully adjusted, would present a combination that includes all the colors of nature. In 1873 H. W. Vogel in Berlin discovered that silver bromide, by treatment with certain aniline dyes, notably eosene and cyanine

* Journal de Physique, 1894, p. 84.
† O. Wiener, Wiedemann's Annalen, June 1895, pp. 225–281.
‡ This Journal, May 1887, p. 349.
§ Royal Institution Lecture, May 17, 1861.

blue, can be made sensitive to waves of much longer period than those hitherto effective in photography. In 1885 he proposed to sensitize plates for each of a number of successive regions in the spectrum, and to make as many complementary pigment prints as negatives, which should then be superimposed. This somewhat complicated plan proved difficult in practice. In 1888 F. E. Ives* of Philadelphia, adopting the more simple Helmholtz-Maxwell modification of Young's theory of color, applied it to the preparation of suitable compound color screens which were carefully adjusted to secure correspondence with Maxwell's intensity curves for the primary colors. The result was a good reproduction of the solar spectrum. But to reproduce the compound hues of nature it is necessary specially to recognize the fact that although the spectrum is made up of an infinite number of successive hues, the three color sensations in the eye are most powerfully excited by combinations rather than simple spectral hues. Thus, according to Maxwell's curves the sensation of red is excited more strongly by the orange rays than by the brightest red rays, but the green sensation is excited at the same time. This fact has to be applied in the preparation of the negatives, while images or prints from these must be made with colors that represent only the primary color sensations. Properly selected color screens must therefore be used for transmission of light to plates sensitized with suitable aniline dyes; and the adjustment of ratios with this end in view is not easy. But it has been successfully accomplished. From three negatives thus made, each in its proper tint, positives are secured; and these are projected, each through its appropriate color screen, to the same area upon a white screen. The addition of lights thus sent from the triple lantern gives the original tints with great fidelity.

Mr. Ives has devised a special form of camera by which the three elementary negatives are taken simultaneously, and also an instrument, the photochromoscope, in which a system of mirrors and lenses brings to the eye a combination similar to that projected with the triple lantern. A double instrument of this kind forms the most perfect type of stereoscope, bringing out with great vividness from the prepared stereographs the combined effect of color, form, and binocular perspective. It is only within the past year that these improvements have been perfected. By further application of the same principles, Mr. Ives has produced permanent colored prints on glass, which do not require to be examined with the aid of any instrument. Each of three negatives is made with a colored screen which transmits tints complementary to those which it

* Journal of the Franklin Institute, January, 1889

is desired to reproduce. The three gelatine films are soaked in aniline dyes of suitable tints, and superimposed between plates of glass. When viewed as a transparency such a print gives a faithful reproduction of the natural colors.

The problem of color reproduction is thus solved, not indeed so simply, but more effectively, than by the method of interference of light, or by those body color methods that have thus far been applied. To the imaginative enthusiasts who are fond of repeating the once novel information that "electricity is still in its infancy," it may be a source of equal delight to believe that photography in colors, a yet more delicate infant, is soon to take the place of that photography in light and shade with which most of us have had to content ourselves thus far. But so long as an instrument is needed to help in viewing chromograms, the popular appreciation of these will be limited. We may take a lesson from the history of the stereoscope. Yet it is gratifying to recognize the great impetus that this beautiful art has received within the last few years. We may quite reasonably expect that the best is yet to come, and that it will have an important place among the future applications of optical science.

The Infra-Red Spectrum.

Among the splendid optical discoveries of this century probably the most prominent are photography and spectrum analysis, each belonging jointly to optics and chemistry. Photography was at first supposed to be concerned only with the most refrangible rays of the spectrum, but Abney and Rowland have photographed considerably below the visible red. Beyond the range thus attained qualitative knowledge was secured by Herschel, Becquerel, Draper, Melloni, Müller, Tyndall, Lamansky and Mouton. But our quantitative knowledge of this region began with the invention and use of the bolometer by Langley,* whose solar energy curve has been familiar to all physicists during the last dozen years. During this interval the bolometer has been used with signal success by Ångström, Rubens, Snow, and Paschen, who have made improvements not only in the instrument itself but in the delicacy of its necessary accompaniment, the galvanometer. The work of Snow† particularly, on the infra-red spectra of the voltaic arc and of the alkalies, and that done by him in conjunction with Rubens‡ on refraction through rock salt, sylvite, and fluorite, exhibited the capacities of the bolometer

* Langley, Selective Absorption of Solar Energy, this Journal, March, 1883, p. 169.

† Physical Review, vol. i, pp. 28 and 95.

‡ Astronomy and Astrophysics, March 1893, p. 231.

even better, perhaps, than Langley's previous work on the sun. But more recently with the collaboration of several able assistants, and more particularly the great ingenuity and mechanical skill of Wadsworth, the sensitiveness of Langley's galvanometer has been so exalted, and the bolometer connected in such manner with photographic apparatus, as to make it an automatically controlled system, by which an hour's work now brings results superior in both quantity and quality to what formerly required many weeks or even months.* Not only is an entire solar energy curve now easily obtained in a single day, but even a succession of them. It becomes thus possible by comparison to eliminate the effect of temporary disturbing conditions, and to combine results in such a way as to represent the infra-red cold bands almost as accurately as the absorption lines of the visible spectrum are indicated by use of the diffraction grating. It will undoubtedly become possible to determine in large measure to what extent these bands are due to atmospheric absorption and which of them are produced by absorption outside of the earth's atmosphere.

With the diffraction grating, supplemented by the radio-micrometer, Percival Lewis† has recently investigated the infra-red spectra of sodium, lithium, thallium, strontium, calcium and silver, attaining results which accord well with the best previously obtained by those who had employed the bolometer, and which demonstrate the exceeding delicacy of the radio-micrometer as an instrument of research.

The Visible Spectrum.

To follow out all the applications of the spectroscope that have resulted in recent additions to our knowledge would carry us far beyond the scope of a single paper. It is possible only to make brief mention of a few.

For a number of years Rowland‡ has been investigating the spectra of all the chemical elements, photographing them in connection with the normal solar spectrum, and reducing them to his table of standards; which is now accepted everywhere. The work is of such magnitude that years more must elapse before its completion. It now includes all wave lengths from 3722 to 7200, and of these the list already published extends as far as wave length 5150; or, from ultra violet nearly to the middle of the green.

Through the spectroscope chiefly has been established during the present year the discovery of the new atmospheric element,

* Langley "On Recent Researches in the Infra-red Spectrum," Report of Oxford meeting of British Association, 1894.

† Astrophysical Journal, June, 1895, p. 1, and Aug., 1895, p. 106.

‡ Ibid., Jan. to Aug., 1895.

argon, by Lord Rayleigh and Professor Ramsay;* its remarkable property of green fluorescence when the electric spark is passed through it in presence of benzene, by Berthelot and Deslandres;† and its association in meteoric iron and various minerals with helium, now proved to be a terrestrial as well as solar element, by Ramsay,‡ Crookes, Lockyer, and others.

With the diffraction spectroscope Rydberg,§ and Kayser and Runge‖ have discovered interesting relations among the spectral lines of a large number of terrestrial elements, arranging them into series whose distribution manifests chemical relationship quite analogous to that indicated in Mendeléeff's periodic law.

By photographing the spectrum of Saturn's rings and noting the relative displacement of the different parts of a spectral line, Keeler¶ has obtained a beautiful direct proof of the meteoric constitution of these rings, a confirmation of the hypothesis put forth by Maxwell in 1859, that the outer portion of the rings must revolve more slowly than the inner portion, and yet not satisfy the conditions of fluidity. His work has been repeated and confirmed by Campbell** at the Lick Observatory.

The spectro-heliograph devised by Hale†† has enabled him to photograph, on any bright day, not only the solar photosphere and spots but also the chromosphere and protuberances. He has made some remarkable attempts with this instrument to photograph the corona without an eclipse, unsuccessful thus far but not without promise of future success.

Polarized Light.

In the domain of polarized light, there have been several noteworthy recent researches. Nichols and Snow‡‡ have shown that calcite, though readily transparent for the brighter rays of the spectrum, rapidly diminishes in power of transmission for waves of short period, so that for the extreme violet this power is scarcely half so great as for the yellow. The transmissive power of this crystal for the infra-red rays, between the wave length limits of 1 micron and 5·5 microns, has been investigated with the bolometer by Merritt,§§ who reaches the

* Proc. Royal Society, Jan. 31, 1895.
† Comptes Rendus, June 24. 1895.
‡ Nature, April 4, May 16, July 4 and July 25, 1895.
§ Wiedemann's Annalen, 1893–1894.
‖ Ibid., 1888–1895.
¶ Astrophysical Journal, May, 1895, p. 416.
** Ibid., August, 1895, p. 127.
†† Astronomy and Astrophysics, March, 1893, p. 256.
‡‡ Philosophical Magazine, V, xxxiii, p. 379.
§§ Physical Review, May–June, 1895, p. 424.

interesting result that the transmission curve for the ordinary ray is wholly independent of that for the extraordinary, the absorption being in general much greater for the former. Several sharp absorption bands are found for each ray. For radiation whose wave length exceeds 3·2 microns the absorption of the ordinary ray is almost complete, so that calcite behaves for such radiation just as tourmaline does for the rays of the visible spectrum. The independence of the two transmission curves is found to exist also for quartz and tourmaline, these curves for the latter crossing each other twice in the infra-red region.

The application of polarized light to the investigation of internal stress in transparent media was made more than forty years ago by Wertheim,* who demonstrated that the retardation of the ray is proportional to the load. An extended series of such experiments has been lately made in this country by Marston,† who, besides confirming Wertheim's conclusion, shows that, "for small strains at least, the colors seen in a strained glass body, when polarized light is passed through it in a direction parallel to one of the axes of strain, are measured by the algebraic difference of the intensities of those two principal strains whose directions are perpendicular to the direction of the polarized light."

A new substance with double rotatory power, like quartz, has been discovered by Wyrouboff,‡ the neutral anhydrous tartrate of rubidium, which is unique in one respect. The rotatory power of the substance in the crystalline state becomes reversed in solution. This wholly new phenomenon introduces some perplexity in connection with certain molecular theories that have been formulated to account for double rotatory power.

Crehore§ has ingeniously applied Faraday's principle of electro-magnetic rotation of the plane of polarization in carbon disulphide to the photographing of alternate current curves. Every variation in the magnetic field causes variation in the amount of light transmitted through a pair of crossed Nicol prisms. The combination becomes a chronograph with an index as free from inertia as the beam reflected from a galvanometer mirror. The same instrument has been applied to measurement of the velocity of projectiles,‖ with results of exceeding interest to the student of gunnery.

* Comptes Rendus, xxxii, p. 289, 1851.

† Physical Review, September–October, 1893, p. 127.

‡ Journal de Physique. III, iii, p. 452, 1894.

§ Transactions of the American Institute of Electrical Engineers, October, 1894, p. 591.

‖ Journal of the U. S. Artillery, vol. iv, No. 3, p. 409, July 1895.

Physiological Optics.

The temptation to dilate upon recent progress in physiological optics has to be resisted. The revision of Helmholtz's great book on this subject was interrupted by the death of the distinguished author, but the last part is now approaching completion under the care of his pupil, Arthur König, who in conjunction with Diederici has done much important work in this domain. The selection of hues for the three primary color-sensations has been slightly modified. Young selected the two extremes of the spectrum, red and violet, together with green, which is about midway between them. The hues now accepted by Helmholtz and those who follow his lead, including the great majority of physicists, are a highly saturated carmine red, an equally saturated ultramarine blue, and a yellowish green, corresponding somewhat to that of vegetation. The red and blue agree with those previously determined by Hering, but the rivalry between the two schools on the subject of color-sensation continues, and perhaps will last through a period commensurate with the difficulty of devising crucial experiments.

Independent theories of color-sensation have been brought out by Mrs. Franklin* in America and by Ebbinghaus† in Germany. The former particularly is worthy of much more extended notice than can here be given. It may perhaps be quite properly called a chemical theory of vision. Light is always bringing about chemical changes in external objects, and the eye is the one organ whose exercise requires the action of light, while such chemical action is implied in the performance of most of the bodily functions, such as the assimilation of food and the oxidation of the blood. The bleaching action of light upon the visual purple, which is continually formed on the retina, has been known ever since the discovery of this in 1877 by Kühne, who secured evanescent retinal photographs in the eyes of rabbits. Mrs. Franklin considers that light-sensation is the outcome of photo-chemical dissociation of two kinds of retinal molecules that she denominates gray molecules and color molecules, of which the latter arise from the gray molecules by differentiation in such a way that the atoms of the outer layer group themselves differently in three directions, and the corresponding action of light of proper wave length gives rise to the three fundamental color-sensations. She develops the theory with much skill, applying it particularly to the phenomena of retinal fatigue and color-blindness. To the objection that

* Christine Ladd Franklin, "Eine neue Theorie der Lichtempfindungen," Zeitschrift für Psychologie und Physiologie der Sinnesorgane, 1892.

† H. Ebbinghaus, "Theorie des Farbensehens," l. c., 1893.

there is no direct proof of the existence of the assumed gray and color molecules, it may be answered that Helmholtz himself fully recognized the uncertainty of the assumption that three different sets of nerves respond to the three fundamental color-sensations, and he admitted that these may be only different activities in the same retinal cone. The supposition of three adjacent cones, responding respectively to the three fundamental sensations, is made only for the sake of greater convenience in discussion.

Indeed there is still much for us to learn regarding the nature of color-sensation. Among the yet unexplained phenomena are those of simultaneous color-contrast. The fact that a small brightly-colored area on a gray background appears surrounded by its complementary tint is familiar enough. For its explanation it has been common to assume that there is unconscious motion of the observer's eyes, incipient retinal fatigue, an error of judgment, or fluctuation of judgment. This has been tested by A. M. Mayer,* who ingeniously devised methods for showing these contrast phenomena on surfaces large enough to match the colors with those of rotating color disks, and thus to arrive at quantitative statements of their hues. When viewed through a small opening in a revolving disk the subjective contrast color was unmistakably perceptible when the duration of passage of the opening was less than $\frac{1}{1000}$th of a second. The same effect was obtained in a dark room with instantaneous illumination of the colored surface by the spark of an electric influence machine. The duration of illumination is thus almost infinitesimal, certainly not more than $\frac{1}{10000000}$ of a second. The hypothesis of fluctuation of judgment is thus shown to be wholly untenable. I have performed most of these experiments, either with Prof. Mayer or separately, and my testimony can therefore be united with his. The case is quite analogous to that of the perception of binocular relief which was once explained as the product of a judgment, but was found to be always possible with instantaneous illumination. Prof. Mayer has devised a disk photometer based on color-contrast, with which the error of a single reading was found much less than with the Bunsen photometer.

The rotating color disk has been applied by O. N. Rood† to the determination of luminosity independently of color by taking advantage of the flickering appearance on a rotating disk upon which two parts have different reflecting powers. An extreme case of this is that of a white sector upon a black disk. At a certain critical speed the retinal shock due to

* This Journal, July, 1893. † Ibid., September, 1893.

momentary impression by white light becomes analyzed into the subjective impression of spectral colors, the duration of the retinal sensation varying with the wave length of the incident light. The law of this variation has been studied by Plateau,* Nichols† and more recently with much precision by Ferry,‡ who showed that retinal persistence varies inversely as the logarithm of the luminosity. For a given source of light separated into its spectral components, the yellow is the brightest. For this hue accordingly the retinal impression is shortest and for violet it is longest.

Under appropriate conditions the after-effect on the retina has a certain pulsatory character, as first noted by C. A. Young§ in 1872, and carefully studied within the last few years by Charpentier‖ in France and Shelford Bidwell¶ in England. A disk with properly arranged black and white sectors, if brightly illuminated and looked at while revolving at a moderate rate, becomes apparently colored, just as a momentary glance at the sun causes the perception of a succession of subjective spectral hues which may last a number of seconds. The phenomenon in relation to the disk was known as early as 1838** and explained by Rood†† in 1860. The re-discovery of what has been long forgotten arouses all the interest of novelty. The "artificial spectrum top" devised by Benham‡‡ last autumn excited interest on two continents, and was promptly copyrighted by a prominent firm of opticians§§ in England. It would perhaps be equally enterprising to copyright the solar spectrum.

The limits of a single address forbid my touching upon the large and practically important subject of color-blindness. Indeed in both physical and physiological optics much has been omitted that is abundantly worthy of attention. In behalf of my hearers it may be wise to take heed, once more, of the fate of Tarpeia, who was overwhelmed with the abundance of her reward.

* Dissertation sur quelques propriétés des impressions produits par la lumière sur l'organe de la vue, Liège, 1829.
† This Journal, October, 1884.
‡ Ibid., Sept., 1892.
§ Philosophical Magazine, vol. xliii, p. 343, 1872.
‖ "Oscillations rétiniennes." Comptes Rendus, vol. cxiii, p. 147, 1891.
¶ On the Recurrent Images following Visual Impressions, Proc. Royal Society, March 27, 1894.
** Fechner, Poggendorff's Annalen, 1838.
†† This Journal, September, 1860.
‡‡ Nature, Nov. 29, 1894, p. 113.
§§ Ibid., March 14, 1895, p. 463.

ART. XL.—*Effect of the Mutual Replacement of Manganese and Iron on the Optical Properties of Lithiophilite and Triphylite;* by S. L. PENFIELD and J. H. PRATT.

THE numerous complete analyses of lithiophilite and triphylite which have been made by Penfield* and Wells† have shown in a striking way the transition from essentially $LiMnPO_4$ to the isomorphous $LiFePO_4$. The pure end products are not known, the lithiophilite richest in manganese being that from Branchville, Conn., with MnO=40·9 per cent and FeO=4·0 per cent, and the triphylite richest in iron that from Rabenstein and Bodenmais, Bavaria, with FeO=36·2 per cent and MnO=9·0 per cent.

Our knowledge of the optical properties of these minerals is confined to the results obtained by E. S. Dana‡ on the lithiophilite from Branchville, who found that the plane of the optical axes was 001, the acute bisectrix at right angles to 010, the divergence of the optical axes large, 2Ha (*n* for the oil being 1·47) =74° 45′ for red and 79° 30′ for blue, the dispersion therefore strong $\rho < v$. The character of the double refraction was found to be positive.

The present investigation has been made upon different varieties of lithiophilite and triphylite and was undertaken in order to determine the variations in the optical properties due to the mutual replacement of manganese and iron. The material was selected from specimens in the Brush collection and from the following localities: Branchville, Conn., three varieties of lithiophilite showing a considerable range in composition; Grafton, N. H., a variety about midway in composition between lithiophilite and triphylite; and Rabenstein near Zwiesel, Bavaria, the nearest approach to theoretically pure triphylite. None of the material showed crystal faces, and the sections and prisms that were prepared were orientated by the cleavages, of which there are two, one fairly good parallel to 001, the other less distinct parallel to 010. The material was not always well adapted for optical work, and it was often quite difficult to obtain sections that were sufficiently transparent. This was due, however, not to any decomposition of the mineral but to numerous crackled and opaque portions of the mass, caused perhaps by crushing. Liquid inclusions were abundant in the material from Branchville.

The cleavage was in no case so perfect that a fragment of suitable orientation for optical purposes could be broken out, and in order to prepare sections and surfaces parallel to a given

* This Journal, xiii, p. 425, 1877; xvii, p. 226, 1879, and xxvi, p. 176, 1883.
† Ib., xvi, p. 119, 1878. ‡ Ib., xvi, p. 119, 1878.

cleavage the following plan was adopted: A fragment showing the desired cleavage was fastened to a glass plate and while the cement was still soft the mineral was shifted in position by means of two small wedges running at right angles to one another until the reflection of a distant object, as a window bar, from the glass plate and the cleavage coincided, when the preparation was turned in different positions, thus showing that the cleavage was parallel to the glass. Then at the sides of the fragment glass plates of equal thickness were cemented, so as to form a large wearing surface, and the mineral ground away until even with the glass. The surface was next polished and a plate or prism prepared as occasion demanded.

The chemical composition of this group of minerals having been fully established by the complete analyses already referred to, the ferrous iron determinations were the only ones required for the present investigation, and these were made by dissolving the minerals in sulphuric acid and titration with potassium permanganate. The composition of the pure end products is as follows:

$$\text{Lithiophilite}\begin{cases} P_2O_5 = 45{\cdot}3 \\ MnO = 45{\cdot}1 \\ Li_2O = 9{\cdot}6 \end{cases} \qquad \text{Triphylite}\begin{cases} P_2O_5 = 45{\cdot}0 \\ FeO = 45{\cdot}5 \\ Li_2O = 9{\cdot}5 \end{cases}$$

Therefore if the amount of FeO is known, the percentage of MnO may be told within 1 per cent by deducting the percentage of FeO from the mean percentage of the bivalent oxides, 45·3.

The results of the investigation are given in the following table:

As seen from the table, the optical characters undergo a very considerable change due to the interchange of manganese and iron, and one that is perhaps greater than might be expected considering how nearly alike the two elements are in atomic weights. With an increase in iron there is an increase in the indices of refraction, and also the divergence of the optical axes changes rapidly. The material from Grafton happened to be of such a composition that it illustrates this latter variation in a very striking manner. In this special case the mineral is practically uniaxial for yellow light, although there was a slight variation in the character of the material, for when the section that was prepared was moved about in the polariscope there were some parts where the interference cross opened up to a very slight extent. At that particular part, however, where the measurements were made the material was uniaxial. Owing to the strong dispersion characteristic of the group, the plane of the optical axes for green was 001, as in the previous cases, while for red it was at right angles to the latter, or 100. The interference figure, therefore, as seen in the polariscope

with white light, was similar to that of brookite, where the extreme colors of the spectrum, red and blue, are dispersed in planes at right angles to one another.

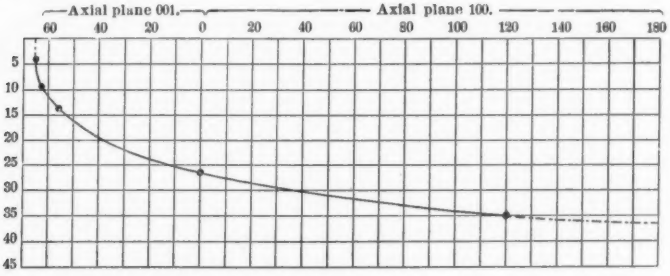
Locality, color, and per cent of FeO.	Indices of refraction and optical orientation. *gr.*=Tl. *y*=Na. *r*=Li.			2Ha over axis *b* in *a*-monobromnaphthalene.	2V over axis *b*.	Plane of the optic axes, character of the dispersion and of the double refraction.
	a	*β*	*γ*			
Branchville.	*gr.*	1·682	....	67° 9′	66° 25′	001
Salmon.	*y.*	1·675	....	66 5	65 13	$\rho<v$
FeO=4·24%	*r.*	1·672	....	65 4	63 23	Positive.
	a=*a*	**b**=*c*	**c**=*b*			
Branchville.	*gr.*	1·682	....	64° 55′	64° 16′	001
Light clove-brown.	*y.* 1·676	1·679	1·687	63 34	62 54	$\rho<v$
FeO=9·42%	*r.*	1·674	....	62 10	61 1	Positive.
Branchville.	*gr.*	1·687	....	59° 56′	59° 20′	001
Light clove-brown with bluish cast.	*y.*	1·682	....	56 59	56 4	$\rho<v$
FeO=13·63%	*r.*	1·678	....	54 32	53 24	Positive.
				2E over axis *b*		
Grafton, N. H.	*gr.* 1·691	1·692	1·698	37° 28′	21° 53′	001
	a=*a*	**b**=*c*	**c**=*b*			Positive.
Light blue or bluish-gray.	*y.* 1·688	1·688	1·692	0°	0°	Uniaxial. Positive.
FeO=26·58%	*r.* 1·683	1·684	1·691	25° 28′	15° 3′	100
	a=*c*	**b**=*a*	**c**=*b*			Positive.
Rabenstein.	....	1·707	....		About 120°	100
Light gray with	....	1·702	....		or 60° over	$\rho<v$
greenish cast.	....	1·697	....		*c* or **a**	Negative.
FeO=35·05%	**a**=*c*	**b**=*a*	**c**=*b*			

The material from Rabenstein was unfortunately poorly adapted for optical work. Numerous sections were cut parallel to the best cleavage, 001, but none was sufficiently transparent to admit of an accurate measurement of the divergence of the optical axes by means of the ordinary axial angle apparatus. By examination with convergent light under the microscope it was seen that the sections were at right angles to the acute bisectrix, and that the plane of the optical axes was 100. By using the most transparent section and the little apparatus devised by Klein,* for examination with polarized light in a liquid whose index of refraction is about like that of the mineral, it was found that the divergence of the optical axes 2Va was about 60° with dispersion $\rho<v$; hence 2V over the crystallographic axis *b*, as given in the previous cases, would be

* Sitz. Ber. Akad. Berlin, xxiv, p. 435, 1891; also Groth's phys. Kryst., 3d edition, p. 750.

120°. By means of a large prism the mean indices of refraction were determined with a fair degree of accuracy.

Although the results are somewhat meager, the authors are perhaps warranted in plotting some of them into a curve, using the percentages of FeO as ordinates and the divergence of the optical axes, 2V, measured in degrees over the axis *b*, as abscissas. This has been done for yellow light only, and it would indicate an interesting relation, for with an increase of FeO over 35 per cent 2V would probably become 180°, that is the material would be again uniaxial, but negative with *c* as the optical axis, and with a still greater increase in FeO the optical axes would have to open up into the pinacoid 010. The plane of the optical axes therefore for the lithiophilite end of the series is 001, for intermediate varieties somewhat nearer triphylite it is 100, and nearer the triphylite end we may expect it to be 010.



Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, July, 1895.

Art. XLI.—*On the Ammonium-Cuprous Double Halogen Salts;* by H. L. Wells and E. B. Hurlburt.

The existence of ammonium-cuprous double halides has long been known, but since no complete investigation of these compounds had been made, a careful study of them has been undertaken.

Mitscherlich* prepared the potassium salt, $4KCl \cdot Cu_2Cl_2$, and mentioned the corresponding ammonium salt. This salt, $4NH_4Cl \cdot Cu_2Cl_2$, has been obtained in the present investigation.

Deherain† described three double chlorides, $4NH_4Cl \cdot Cu_2Cl_2 \cdot H_2O$, $2NH_4Cl \cdot Cu_2Cl_2$ and $NH_4Cl \cdot Cu_2Cl_2$. The first of these salts, if the molecule of water is omitted, corresponds to the compound mentioned by Mitscherlich which we have

* Ann. Chim. Phys., lxxiii, 384. † Comptes Rendus, lv, 808.

obtained, and we are convinced that Deherain's formula for it is wrong. The second salt, $2NH_4Cl . Cu_2Cl_2$, has not been obtained by us, but since it corresponds in type to a bromide and an iodide which are easily prepared, its existence seems possible. The third salt of Deherain, $NH_4Cl . Cu_2Cl_2$, probably does not exist, for we have failed to obtain it, as has Ritthausen also. Ritthausen,* while not being able to prepare $NH_4Cl . Cu_2Cl_2$, obtained the compound $4NH_4Cl . 3Cu_2Cl_2$, and we have confirmed this result. The compositions required for the two formulæ do not differ widely, so that it is probable that Deherain analyzed the salt $4NH_4Cl . 3Cu_2Cl_2$ and gave it an incorrect formula.

As far as we know, no double bromides have been previously described. Saglier† has described an ammonium-cuprous iodide, to which the formula $2NH_4I . Cu_2I_2 . H_2O$ is given. The single double iodide which we have obtained corresponds to Saglier's description and to his formula, except that we have found it to be undoubtedly anhydrous.

In the present investigation a great number of experiments have been made, with gradually varying proportions of the constituent salts in each case, in order to obtain as many compounds as possible.

The Chlorides, $4NH_4Cl . Cu_2Cl_2$ *and* $4NH_4Cl . 3Cu_2Cl_2$.— These compounds were prepared by making hot hydrochloric acid solutions of mixtures of the simple salts, usually in the presence of copper wire, and cooling to crystallization. The first salt mentioned above is very readily oxidized by exposure to air, hence it has been found advisable in making it to use a flask and to protect the solution from air by means of a stream of carbonic acid.

The compound $4NH_4Cl . Cu_2Cl_2$ requires the presence of a comparatively large amount of ammonium chloride for its formation and crystallizes in colorless prisms which rapidly change in color through brown to green upon exposure to the air. Crystals 20^{mm} in length and 5^{mm} in thickness were observed.

The following analyses of two separate crops were made:

			Calculated for $4NH_4Cl . Cu_2Cl_2$.
Ammonium	17·91	18·12	17·48
Copper	29·69	29·28	30·79
Chlorine	50·66	50·37	51·73
	98·26	97·77	100·00

* J. pr. Ch., lix, 369. † Comptes Rendus, civ, 1440.

It was necessary to dry the samples for analysis very rapidly on account of their instability, and some water was unavoidably left in them, causing the low summations. The amount of water corresponding to one molecule (Deherain's formula) is 4·19 per cent.

The other chloride, $4NH_4Cl \cdot 3Cu_2Cl_2$, is produced when the simple salts are mixed in the required proportion in hydrochloric acid solution, and also under considerable variations from these proportions. It forms brilliant, colorless dodecahedrons which are moderately stable in the air at ordinary temperatures, but gradually turn green on exposure.

The following analyses of three separate crops were made:

	I.	II.	III.	Calculated for $4NH_4Cl \cdot 3Cu_2Cl_2$.
Ammonium	9·39	9·73	9·73	8·92
Copper	47·19	46·73	46·79	47·15
Chlorine	42·81	43·11	43·13	43·93
	99·39	99·57	99·65	100·00

The calculated amounts of ammonium, copper and chlorine for Deherain's formula, $NH_4Cl \cdot Cu_2Cl_2$, are 7·15, 50·50 and 42·35 respectively, and it does not seem possible that this formula represents the true composition of the salt, because the samples analyzed were well crystallized and evidently very pure.

The Bromides, $4NH_4Br \cdot Cu_2Br_2$ and $2NH_4Br \cdot Cu_2Br_2 \cdot H_2O$.—By the use of ammonium bromide, cuprous bromide, hydrobromic acid and copper wire, these compounds were produced similarly to the chlorides, but since these salts oxidize much less readily than the chlorides, no protection by means of carbon dioxide was necessary in any case.

The first salt, $4NH_4Br \cdot Cu_2Br_2$, is formed in the presence of an excess of ammonium bromide and resembles the corresponding chloride in form, occurring in long, colorless prisms which turn green after long exposure to the air. Analyses of two separate crops gave:

	I.	II.	Calculated for $4NH_4Br \cdot Cu_2Br_2$.
Ammonium	10·24	10·24	10·61
Copper	18·81	18·47	18·68
Bromine	70·93	70·60	70·71
	99·98	99·31	100·00

The other bromide, $2NH_4Br \cdot Cu_2Br_2 \cdot H_2O$, is formed in the presence of a relatively greater amount of cuprous bromide. It forms brilliant, colorless rhombohedrons, sometimes 15^{mm}

long and 9mm wide, and it is more stable in the air than the first bromide. Analyses of two separate crops gave:

	I.	II.	Calculated for $2NH_4Br . Cu_2Br_2 . H_2O$.
Ammonium	6·88	6·90	7·19
Copper	25·61	25·20	25·32
Bromine	63·76	64·08	63·90
Water (difference)	3·75	3·82	3·59

The Iodide, $2NH_4I . Cu_2I_2$.—Only one double iodide could be obtained by the use of ammonium iodide and cuprous iodide in widely varying proportions in hydroiodic acid solutions. This circumstance agrees with the observation made upon several other series of double salts studied in this laboratory, that the number of double salts possible decreases from the chlorides to the iodides. Two separate crops gave the following results upon analysis:

	I.	II.	Calculated for $2NH_4I . Cu_2I_2$.
Ammonium	5·84	5·95	5·36
Copper	18·75	----	18 90
Iodine	75·07	75·55	75·74
	99·66		100·00

Summary.—The double salts obtained in the present investigation are as follows:

2 : 1 Type.	1 : 1 Type.	2 : 3 Type.
$4NH_4Cl . Cu_2Cl_2$	----------	$4NH_4Cl . 3Cu_2Cl_2$
$4NH_4Br . Cu_2Br_2$	$2NH_4Br . Cu_2Br_2 . H_2O$	----------
----------	$2NH_4I . Cu_2I_2$	----------

The two bromides are apparently new compounds, while a formula without water has been given to Saglier's iodide. The compound, $NH_4Cl . Cu_2Cl_2$, of Deherain probably does not exist.

It was hoped that ammonium-cuprous salts of other types, corresponding to the cæsium-cuprous salts described by one of us* would be found, but such has not been the case, and there is no correspondence between the two series. The view advanced in the article just mentioned, that the formula $4NH_4Cl . 3Cu_2Cl_2$ might be considered somewhat doubtful on account of its complexity and because its variation from the 1 : 2 type is slight, seems to have been unfounded.

Sheffield Scientific School, New Haven, Conn., June, 1895.

*This Journal, xlvii, 96.

Art. XLII.—*On some Phonolitic Rocks from Montana;* by L. V. Pirsson.

Of the two rock types described in the following note the first was collected from a drift bowlder on the Missouri River near Fort Claggett by Mr. W. H. Weed of the U. S. Geological Survey, the second also from a drift bowlder in the ballast material of the Great Northern Railway, at Havre by the author. The occurrence of these two closely related types, the one on the north and the other on the south of the Bear Paw Mountain, certainly renders it probable that they have been derived from this little known mountain group and greatly heightens our interest concerning it.

While in the present stage of petrological knowledge the description of rocks devoid of their geological mode of occurrence and genetic relationships is of little use or interest, in the present case the types are so unusual and present so many features of petrological and mineralogical interest that it has been thought best to give a brief account of them. Moreover, the rocks have so strongly marked a habit that it has been thought well to call attention to them, since when their place of occurrence becomes known, they cannot fail to be of great service in tracing the movement of the drift in the region in which they are found. They add one more to the hitherto small number of occurrences of phonolite in this country.

Pseudo-leucite sodalite tinguaite.

Megascopically, the rock is of a very dark stone color with a strong greenish tinge. It is aphanitic, tough, dense and compact. On weathered surfaces it is a clear, rather dark green. Through this material, which forms the tinguaitic ground-mass, are scattered large white crystals which attain a diameter of $1\frac{1}{2}^{cm}$, are sometimes not above a quarter of this in size but usually average about 1^{cm} in diameter, and are so thickly scattered that commonly they are scarcely separated from each other by more than their own diameters. They are white to pale gray in color and have a greasy, waxy luster. In outline they are nearly spherical but generally show more or less crystal boundaries and most commonly approach octagons, in some cases showing the figure quite perfectly. They present in fact the different sections which may be obtained by passing planes through the icositetrahedron. They appear precisely like leucites but are in fact pseudomorphs after that mineral, as will be shown later.

Thickly scattered everywhere between these large pseudo-leucites are small white or pinkish-colored crystals which run from 1 to 2^{mm} in diameter, also spherical in form but which occasionally show sections characteristic of the dodecahedron. These are sodalites.

These two minerals, together with a rare occasional feldspar, tabular in form and 2 or 3^{mm} long, form the only phenocrysts. The rock is so thickly spotted with them that as a result of the contrast of their white color with that of the dark ground-mass it has a strongly mottled appearance that is extremely characteristic.

On weathered surfaces the pseudo-leucites assume a pale brown color and show a zonal weathering, in that they exhibit an outer shell about 1^{mm} in thickness, which is succeeded by a thin shell of more spongy material. On fresh surfaces this outer zone may also be seen by a slightly different color and luster from the rest of the crystal.

The sodalites on weathered surfaces turn brown and disappear easily, leaving pits in their former places.

When the rock is powdered and treated with acid it gelatinizes so readily and strongly as to show a very large proportion of high alkali silicates present. The solution in nitric acid yields an abundant precipitate with silver nitrate, indicating a large amount of sodalite in the rock.

Microscopic.—In thin section the microscope discloses the following minerals as present: Titanite, ægirite augite, ægirite, sodalite, orthoclase, nephelite, fluorite, calcite and several unknown minerals; the pseudo-leucite is a mixture of orthoclase and nephelite.

Pseudo-leucite.—Under the microscope these are seen to be made up in general of an allotriomorphic mosaic of orthoclase and nephelite. In some cases the outer edge of the section is composed of orthoclase crystals with their longer axes perpendicular to the crystal faces of the original leucite. They form in fact the outer shell previously mentioned. Such an arrangement is similar to that of pseudo-leucites from Brazil and Magnet Cove, as noted by Graeff* and J. Francis Williams.† Inside of this shell, which is rarely perfect, the usual granitoid mixture occurs. At times the orthoclase laths in the center of the pseudo-leucite are grouped around some common point, forming a sphero-crystal, and a number of these may occur in the same pseudo-leucite. Again at other times the orthoclase contains small streaks and patches of nephelite in such a way as to give rise to a distinct micro-pegmatitic structure.

* Jahrb. f. Min., 1887, vol. ii, p. 257.

† Arkansas Geol. Surv., Ann. Rep., 1890, p. 268.

The orthoclase and nephelite composing the pseudomorph are fresh and clear, save a slight incipient kaolinization of the feldspar. Besides these minerals there are a few small included crystals of ægirite and some small crystals of minerals to be noted later.

Portions of these pseudomorphs were obtained and carefully freed from any of the surrounding matrix, powdered and treated with dilute nitric acid. After filtering, the solution gelatinized readily on evaporating and gave a strong reaction for soda, while only a doubtful trace of potash was present. This proves that occasional small patches of isotropic substance are either sodalite or analcite and not any original unchanged leucite substance.

Pseudo-leucites of the character described above were first found in Brazil by Derby. Graeff* believed them to be inclusions of eleolite-syenite, but Hussak† showed that they were in all probability to be referred to original leucites, a conclusion which was confirmed by the studies of precisely similar occurrences in tinguaite from Magnet Cove by J. Francis Williams.‡

Titanite.—This occurs rather rarely in small crystals about ·5^{mm}. It has the usual characters.

Ægirite-augite.—Phenocrysts of augite are very rare. A few of a green variety with deep green ægirite borders have been noted 1 to 2^{mm} long.

Sodalite.—The crystals are very fresh and do not show any signs of alteration or zeolitization; a little infiltrated calcite in cracks is now and then seen.

They are filled with interpositions of extremely minute crystallites which are perhaps ægirite. They usually show by the arrangement of these a zonal structure. They are quite idiomorphic, and in the few cases where they touch orthoclase, they project into it with crystal boundaries. The small ægirites of the ground-mass usually surround them in such a way as to form green wreathes.

Orthoclase.—The large orthoclase phenocrysts are very rare; they are quite fresh save for incipient kaolinization.

The ground-mass in which these phenocrysts lie is made up of a felt of alkali feldspars in small lath-like forms and ægirite needles. The structure is pronouncedly trachytic but has a strong fluidal tendency, especially around the large phenocrysts, about which the streams of microlites bend and twist. Between the feldspar microlites are small formless patches of nephelite which only very occasionally show a crystal outline.

Fluorite.—This is found scattered through the rock in

* Jahrb. f. Min., 1887, vol. ii, p. 257.
† Ibid., 1890, vol. i, p. 167.
‡ Arkansas Geol. Surv. Ann. Rep., 1890, vol. ii. p. 267.

masses and stringers which are occasionally clearly visible to the naked eye. It occurs very commonly at times in the center of the large pseudo-leucite crystals or in vein-like masses filling cracks from the outer boundary. It has the usual unequal distribution of its violet pigment. The occurrence of the mineral renders it probable that its origin is due to pneumatolytic processes.

In the center of the pseudo-leucites there frequently occur small crystals of an unknown mineral. Its habit is that of a rather stout prism which rarely exceeds ·5^{mm} in length and is usually much smaller. It is bounded by well defined crystal planes. Examined with a lens in the hand-specimen, they are seen to be of a brown color with a resinous luster. It has a good cleavage parallel to one of the long prism planes. Placed on this cleavage face under the microscope the following optical properties appear. The extinction is parallel to the prism edge and a positive bisectrix emerges in the center of the field, the plane of the optic axes being parallel to the long prism edge. There is a not very strong pleochroism parallel to the prism edge = a = brown, at right angles = b, a yellow. It was at first thought that the mineral might be astrophyllite, and three small crystals, all that could be obtained, were tested for MnO and TiO_2, for the former in a sodium carbonate bead, which was then dissolved in a minute quantity of H_2SO_4 and tested for TiO_2 with hydrogen peroxide. No reaction was obtained in either case, though a nearly equal quantity of astrophyllite from Brevig treated in the same way gave excellent reactions for both. The small solution of the mineral was then tested for iron, which was present. The mineral is not astrophyllite, both on chemical and optical grounds.

If we assume that the prism edge represents the vertical axis and the cleavage face is *a*(100), then the above facts and those learned by a study of the sections may be summarized as follows:

Orthorhombic, the pinacoids *a*(100) and *b*(010) present with long tapering pyramids or domes. Cleavage parallel to *a*(100). Axial plane parallel to *b*(010). And a = *c*, b = *b*, c = *a*. Color brown, luster resinous, pleochroism not marked, a brown, b yellow, c between. Scarcely perceptible in thin section. Refraction high, at least 1·6. Double refraction high, at least ·04. Does not contain MnO; contains not more than a trace of TiO_2; iron is present.

These properties distinguish the mineral from astrophyllite, låvenite, rinkite, mosandrite and cossyrite, which might be expected to occur in a rock of this nature. It is to be hoped that better and more abundant material may be discovered

when the locality of this rock is found and its exact nature determined.

Besides this mineral, there is another present in the rock, which occurs in grains and in one case in a hexagon-shaped section, nearly always enclosed in sodalite and associated with fluorite. The double refraction is extremely low and in places the mineral appears isotropic. It appears much like apatite, but the hexagonal section shows the strongest double refraction seen (which cannot be over ·006) and does not extinguish parallel to an edge. The mineral is colorless. It is thought to be eudialyte, but it must be admitted that the determination is very doubtful.

Since the geological position of this rock is unknown, no analysis of it has been made. It would not differ materially from those already made of almost precisely similar rocks from other localities, and it could not be used in solving the general petrologic problems of the region.

Quartz tinguaite porphyry.

Megascopically, the rock shows a dense green ground-mass very similar to the type previously described, in which are very thickly scattered phenocrysts of feldspar. The feldspars are strongly tabular and somewhat columnar in habit and range from 1 to $1\frac{1}{2}^{cm}$ across the flat face (b 010) and from 3 to 5^{mm} in thickness. They show by a pronounced parallel arrangement an excellent flow-structure in the rock. It seems probable that the specimen is from a dike with the feldspars arranged parallel to its walls, as this is the most common way in which rocks of this type occur.

Microscopically, the following minerals are found present: Amphibole, ægirite-augite, ægirite, albite, orthoclase and quartz.

The *amphibole*, which occurs in short, rather stout prisms, is rather rare. The prisms are from ·5 to $·2^{mm}$ in length. It has a low double refraction and rather large extinction angle and is quite pale in color. Pleochroism not marked. c, light brownish green, b very pale brown, a medium leather brown, absorption $a > c > b$. Apt to be altered.

Ægirite-augite.—As usual, also often altered to ferruginous products. Enclosed in the feldspar phenocrysts, it shows its previous formation.

Orthoclase.—From their optical properties, as shown on cleavage fragments, the large phenocrysts are to be referred to this mineral. They contain inclusions of slender lath-like feldspars which from their twinning, etc., are believed to be of albite-oligoclase; they also contain enormous quantities of minute microlites of a mineral of rather high refraction occurring in grains and short prisms. This is thought to be augite.

The ground-mass in which the above phenocrysts lie appears much like that of the preceding rock, it is a compact felt of small laths of orthoclase (probably with more or less anorthoclase) and slender needles of ægirite often arranged in beautiful flow structures. Scattered through this are small irregular patches of quartz. This rock, on treatment with acid, does not show a trace of gelatinization, thus confirming the absence of nephelite. The quartz, of course, was optically proved.

Use of the term "tinguaite."—As is well known, Rosenbusch* first gave this term to phonolitic rocks from Brazil previously described by Graeff.† According to the idea expressed by him, they filled a definite position in his system of "dike" rocks.

Later, however, Derby,‡ from whom the original types had been received, states that they occur in effusive masses as well as in dike forms. On this account some writers have rejected the term. It seems to us, however, that as a name by which to designate those fine-grained porphyritic rocks which contain large amounts of ægirite in the ground mass, if used without regard to their geological mode of occurrence, the name is a very useful one for field and petrographic purposes and deserves to be retained. As a sequence of the abundance of ægirite needles in the ground-mass, such rocks have a distinct megascopic habit and color that it is very useful to recognize.§

* Mass. Gest., p. 628, 1887.

† Jahrb. für Min., 1887, vol. ii, p. 257.

‡ Quart. Jour. Geol. Soc., vol. xlvii, p. 254, 1891.

§ While the above article was passing through the press the author received Prof. W. C. Brögger's important and interesting work "Die Gesteine der Grorudit-Tinguait Serie," a previous sending having been lost in the ill-fated Elbe. The quartz tinguaite described above corresponds very closely with the "Grorudite" of Brögger, differing chiefly in the presence of the large feldspar phenocrysts. Brögger recognizes the difficulty of differentiating the phonolites occurring in flows from those in dikes and proposes to divide the group into those rich in lime (carrying hauyn and nosean) and those poor in lime (0·5–2·0 per cent) but rich in ægirite and nephelite, and thereby having the characteristic green color. The term tinguaite is to be reserved for the latter. This is essentially the same idea as that proposed above though in a somewhat more limited sense.

In adverting to Derby's article Brögger states that Derby does not say that the Brazilian tinguaites occur in effusive flows. This is true, but it is nevertheless precisely the idea that the writer, along with others, understands that he wishes to convey. It is to be hoped that Prof. Derby himself will see fit to clear up this matter, about which so much misapprehension seems to exist.

Mineralogical-Petrographical Laboratory,
Sheffield Scientific School of Yale University, New Haven, July, 1895.

Art. XLIII.—*The Reduction of Selenic Acid by Hydrochloric Acid;* by F. A. Gooch and P. S. Evans, Jr.

[Contributions from the Kent Chemical Laboratory of Yale College—XLV.]

It has long been known that selenic acid is reducible by hydrochloric acid with evolution of chlorine, but the reaction was regarded as more or less uncertain until Petterson showed* that conditions of action may be secured under which the reduction proceeds so regularly that the chlorine evolved may be estimated iodometrically and taken as the measure of the selenic acid originally present, or of the selenious acid produced. According to this method of determination, it is only necessary to boil a solution of selenic acid in hydrochloric acid of moderate concentration, and if the solution is not too dilute the reduction is obtained in a few moments. Petterson did not, however, fix with exactness the limits of dilution within which a successful determination of the selenic acid may be expected. The object of this paper is to record the results which we have obtained in studying more closely the conditions necessary to an accurate and rapid reduction. We have used in our experiments solutions of selenic acid prepared by oxidizing pure, white, resublimed selenium dioxide according to the method laid down in a previous paper from this laboratory† for the quantitative determination of that substance. A portion of the crystalline oxide, approximately two grams, was carefully weighed, dissolved in 120 cm^3 of water containing one-twelfth of its volume of sulphuric acid, and treated with a strong solution of potassium permanganate until the color characteristic of a distinct excess of that reagent prevailed distinctly over that of the brown oxide of manganese thrown down in the oxidation. The liquid was warmed to about 50° C., bleached by oxalic acid, and the excess of this reagent was destroyed by more permanganate. On account of the tendency of manganous salts, when present in considerable amount in warm solutions containing but little free acid, to react upon any considerable excess of permanganate with the deposition of higher oxides of manganese, it is generally necessary to repeat the bleaching and oxidizing process two or three times before the final color of a slight excess of the permanganate remains in clear solution and indicates the completion of the oxidation of the selenium. Finally, the liquid was filtered, diluted carefully to the volume of one liter, and used as a standard solution.

* Zeitschr. Anal. Chem., xii, 287.

† Gooch and Clemons: this Journal, l, 51.

To determine in a general way the point of dilution at which mixtures of selenic and hydrochloric acids yield chlorine, we submitted various mixtures to distillation in a retort arranged with an inverted condenser (so that the aqueous distillate might be constantly returned to the retort) which was joined to an absorbtion apparatus charged with a solution of potassium iodide. A current of carbon dioxide was passed through the apparatus during the distillation, to carry forward whatever chlorine might be evolved in the process. The iodine liberated in the absorbtion apparatus was determined by titration with standard sodium thiosulphate. The results of these experiments are given in the accompanying table.

SeO_3 present. grm.	Total volume. cm^3	Per cent of HCl, sp. gr. 1·20, by volume.	Time in minutes.	Chlorine in terms of the theoretical total.
0·1144	100	5	5	None
"	"	10	"	None
"	"	15	"	About 1%
"	"	20	"	" 7%
"	"	25	"	" 30%
"	"	30	"	" 70%

It is plain that so long as the volume of the hydrochloric acid, sp. gr. 1·20, does not amount to more than ten per cent of the entire liquid no chlorine whatever is evolved, and that only when the percentage of this acid rises as high as thirty does the chlorine evolved during boiling for five minutes approach the theoretical yield. In the ordinary process of distillation, in which the inverted condenser is not used, the liquid must gradually concentrate and the acid become stronger, so that under such conditions the yield of chlorine in a definite period of time must generally be greater than that obtained in the corresponding experiments of the table. Obviously it is advantageous, in attempting the practical reduction of selenic acid, to begin the distillation with acid of strength sufficient to insure the evolution of chlorine in quantity at the outset, and we have found it best to start with a mixture one-third of which is the strongest aqueous hydrochloric acid, sp. gr. 1·20. With solutions so constituted the reduction goes on rapidly. We have found, however, that care must be taken not to prolong the boiling after the solution reaches a concentration corresponding to hydrochloric acid of half-strength; for under such conditions—attained in our experiments either by boiling down mixtures of selenious acid and hydrochloric acid, or by making mixtures of selenious acid containing hydrochloric acid of half-strength—we have found that selenium appears visibly in the distillate, while iodine is set free from the iodide in the receiver. Good results may be

expected when the mixture, containing one-third of its volume of the strongest aqueous hydrochloric acid at the beginning, is boiled until all chlorine is expelled, care being taken that the volume of the liquid shall not become less than two-thirds of the original volume.

These are conditions which are easily kept; and we have found that from solutions having a total volume of 75 cm^3 and containing 25 cm^3 of the strongest aqueous hydrochloric acid (sp. gr. 1·20), the entire amount of chlorine corresponding to the reduction of 0·2 grm. of selenic acid to selenious acid is liberated in ten minutes. The details of these experiments are given in the accompanying table.

$Se = 79{\cdot}1,\ O = 16.$

SeO_3 taken. grm.	Total volume at the outset.	HCl, sp. gr. 1·20, present.	Time in minutes.	SeO_3 found. grm.	Error.
0·0572	75 cm^3	25 cm^3	10	0·0568	0·0004—
0·0572	"	"	"	0·0569	0·0003—
0·1144	"	"	"	0·1143	0·0001—
0·1144	"	"	"	0·1137	0·0007—
0·1144	"	"	"	0·1147	0·0003+
0·2288	"	"	"	0·2233	0·0005—
0·2288	"	"	"	0·2279	0·0009—

ART. XLIV.—*The Reduction of Selenic Acid by Potassium Bromide in Acid Solution;* by F. A. GOOCH and W. S. SCOVILLE.

[Contributions from the Kent Chemical Laboratory of Yale College—XLVI.]

IT has been shown in previous papers from this laboratory that potassium bromide may be used with good effect in presence of acid and under well-defined conditions as a reducer of arsenic and telluric acids. This paper gives the results of similar experiments made to test the interaction between the bromide and selenic acid.

In our experiments we have used selenic acid carefully prepared by oxidizing pure, white, re-sublimed selenium dioxide by means of potassium permanganate in the manner described in the preceding paper. When intermixed with sulphuric acid and potassium bromide, selenic acid liberates bromine in proportion to the excess of acid, the bromide, and the elevation of the temperature. When such a solution is boiled the bromine is evolved and may be collected in potassium iodide contained in any appropriate receiver, and the iodine

thus set free may be determined by standard sodium thiosulphate and taken as the measure of the bromine distilled. We have found an apparatus previously used in this laboratory in similar work (made by sealing the exit tube of a Voit wash-bottle, used as a retort, to the inlet tube of a Drexel wash-bottle used as a receiver, with a set of Will and Varrentropp absorbtion bulbs sealed to the outlet tube of the receiver, to serve as a trap) extremely convenient in the distillation process, and a current of carbon dioxide passed slowly through the apparatus aids greatly in carrying the bromine to the receiver and in promoting quiet boiling. We find that the applicability of the reaction to quantitative purposes turns upon the adjustment of the proportions of the reagents used. The following table contains the results obtained by varying the relative amounts of acid and bromide and the time of boiling. The selenium trioxide recorded as found is calculated upon the assumption that selenious acid is the product of the reduction according to the equation,

$$H_2SeO_4 + 2HBr = H_2SeO_3 + H_2O + Br_2$$

Se = 79·1, O = 16

SeO_3 taken as H_2SeO_4. grm.	H_2SO_4 of half-strength. cm³.	KBr taken. grm.	Initial volume. cm³.	Final volume. cm³.	SeO_3 found. grm.	Error. grm.
(1) 0·1145	5	1	60	25	0·1140	0·0005 −
				15	0·1193	0·0048 +
(2) 0·1145	5	5	60	30	0·1134	0·0011 −
				23	0·1184	0·0043 +
(3) 0·1145	10	1	60	27	0·1134	0·0011 −
				23	0·1141	0·0004 −
(4) 0·1145	20	1	60	35	0·1152	0·0007 +
(5) 0·1145	20	1	60	35	0·1144	0·0001 +
(6) 0·1145	20	5	60	45	0·1172	0·0027 +

From these results it is apparent that the amount of iodine set free in the receiver is dependent upon the proportion of the bromide, the strength of the acid, and the degree of concentration during the distillation. When the proportions of sulphuric acid, potassium bromide, and selenic acid are favorable, the bromine liberated is removed rapidly to the distillate, leaving the residue perfectly colorless, but as the distillation is continued the liquid residue again takes on color and more iodine is set free by the action of the distillate upon a clear solution of potassium iodide, while selenium is plainly visible in the receiver. When the amount of potassium bromide is large its effect is to retain bromine in the liquid so obstinately that no period of colorlessness intervenes before the second stage of color arrives; when its amount is small while that of

the sulphuric acid is also small, the reduction of the selenic acid and the evolution of the bromine progress slowly; and when the amount of bromide is small while that of the acid is comparatively large, the interval of colorlessness is prolonged. The proportions which we found best in handling 0·25 grm. of selenic acid, or less, are an initial volume of 60 cm³ containing 20 cm³ of sulphuric acid of half-strength with 1 grm. of potassium bromide. Under these conditions we find, as in experiments (4) and (5) of the previous table, that the reduction is almost theoretically exact when the distillation is continued until the re-coloration of the boiling liquid is distinctly recognizable; and this point corresponds in practice very closely to a concentration of volume to 35 cm³. In the following table are gathered the results of further experiments in which these conditions of action were preserved:

SeO_3 taken as H_2SeO_4. grm.	H_2SO_4 of half-strength. cm³.	KBr taken. grm.	Initial volume. cm³.	Final volume. cm³.	SeO_3 calculated. grm.	Error. grm.
0·0590	20	1	60	35	0·0588	0·0002—
0·0590	20	1	60	35	0·0591	0·0001+
0·0614	20	1	60	35	0·0616	0·0002+
0·0614	20	1	60	35	0·0607	0·0007—
0·1180	20	1	60	35	0·1177	0·0003—
0·1180	20	1	60	35	0·1180	0·0000
0·1534	20	1	60	35	0·1527	0·0007—
0·2349	20	1	60	35	0·2350	0·0001+

It is plain from these results that, if the conditions of action which we have indicated are observed, the reduction proceeds with regularity sufficient to warrant the use of the reaction as an analytical process.

ART. XLV.—*The Reptilia of the Baptanodon Beds;* by O. C. MARSH.

THE Baptanodon beds form a distinct horizon in the Jurassic of the Rocky mountain region, their position being just above the red Triassic sandstones, on which they rest unconformably, and immediately below the Atlantosaurus beds. They consist entirely of marine strata of shales, limestones, and sandstone, and contain a peculiar invertebrate fauna in which *Belemnites densus*, M. and H., is a characteristic fossil.

The writer first recognized this horizon and determined its Jurassic age, in 1868, near Lake Como, in Wyoming, where the strata are well developed, and their geological position is clearly defined in the characteristic section at Como Bluff. In 1870, the writer again found the same horizon in the Green river valley, in Utah, on the eastern flank of the Uinta mountains. Here, also, he discovered the first vertebrate remains detected in the horizon, the most characteristic of which pertained to a small crocodile. The humerus was only five inches in length. The shaft is slender, and the distal end one and one-fourth inches in width. This animal may be referred to the genus *Diplosaurus*, found in the Atlantosaurus beds above, and the species be known as *Diplosaurus nanus*.

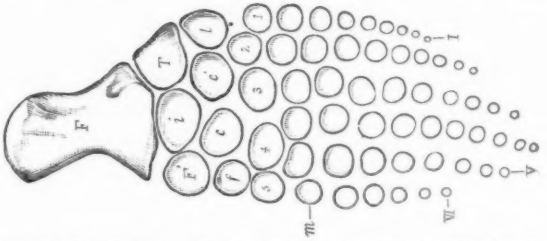


FIGURE 1.—Left hind paddle of *Baptanodon discus*, Marsh. One-eighth natural size.

Several years later, the writer carried on extensive explorations in this horizon in the Como region of Wyoming, and here was found the skeleton of the large saurian which has since given the name to the horizon. This new reptile, nearly allied to *Ichthyosaurus*, but without teeth, was first called *Sauranodon natans* by the writer,* but, as the generic name proved to be preoccupied, it was replaced by *Baptanodon*, and at the same time the paddle of a second species was figured (vol. xix, p. 491), and this is also shown in figure 1 above. A vertebra of the type species is represented in figure 2.

Subsequent researches brought to light a number of other specimens in the same region, and still others were obtained from more distant localities in the same horizon.

* This Journal, vol. xvii, p. 86, January, 1879.

A single vertebra, apparently of this genus, was obtained by the writer, in 1873, in eastern Oregon, and with it a *Trigonia*, both found in the Blue mountains. The locality was not visited by the writer, and he has no conclusive evidence that the horizon, apparently Jurassic, is the same as that in the Como region where the type of *Baptanodon* was found.

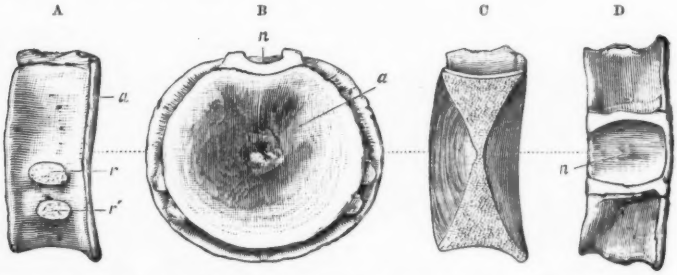


FIGURE 2.—Cervical vertebra of *Baptanodon natans*, Marsh. One-third natural size. *A*, side view; *B*, front view; *C*, section; *D*, top view; *a*, anterior articular face; *n*, neural canal; *r*, *r'*, faces for rib.

In 1885, a new outcrop of the Baptanodon beds was found in the Freeze Out mountains in Wyoming, and here several skeletons of *Baptanodon* were obtained, all in concretions of limestone, as in the original locality. One concretion from this new locality enclosed the skeleton of a small Plesiosaur of much interest, being the first Jurassic form observed in this country. This specimen was named by the writer *Parasaurus striatus*, the specific term denoting a characteristic feature of the vertebræ, which are all strongly grooved, as indicated in the one shown in figure 3, below.* This generic name also proved to be preoccupied, and was replaced by *Pantosaurus*,† the name of the species now being *Pantosaurus striatus*.

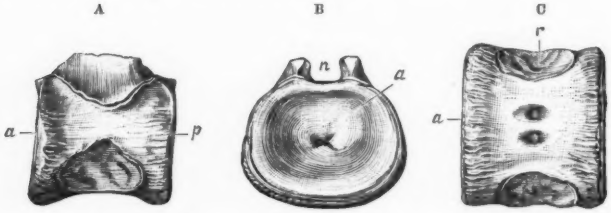


FIGURE 3.—Posterior cervical vertebra of *Pantosaurus striatus*, Marsh. One-half natural size. *A*, side view; *B*, front view; *C*, bottom view; *a*, anterior face; *n*, neural canal; *p*, posterior face; *r*, face for rib.

The skull in this genus was provided with teeth. The neck was long and slender. The vertebræ preserved resemble most nearly in form and size those of *Plesiosaurus plicatus*, Phillips.

Yale University Museum, October 16, 1895.

* This Journal, vol. xlii, p. 338, 1891. † Report Geological Congress, 1891, p. 159.

ART. XLVI.—*Restoration of Some European Dinosaurs, with Suggestions as to their Place among the* REPTILIA;* by O. C. MARSH. (With Plates V–VIII.)

FOR several years, I have been engaged in investigating the Dinosaurs of North America, where these extinct reptiles were very abundant during the whole of Mesozoic time. The results of my study have been published from time to time, and I have already had the honor of presenting some of these to the British Association. In carrying out this investigation so as to include the whole group of Dinosaurs, wherever found, and bringing all under one system of classification, it has been necessary for me to study the remains discovered in Europe, and I have made several visits to this country for that purpose.

In comparing the forms known from the two continents, certain important differences as well as some marked resemblances between the two have been observed, and placed on record. In concluding my investigations of the North American forms, I have fortunately been able to make restorations of the skeletons of quite a number of very complete type specimens, and this has proved a most instructive means of comparing those from different horizons, and of different groups, among the known *Dinosauria* of America.

The success of this plan rendered it very desirable to extend it, if possible, to the best-known forms of European Dinosaurs. This I have been enabled to do in a few instances, and the main object of the present paper is to lay these latest results before you.

In approaching the subject of European Dinosaurs, and especially those of England, where the study of the group first began, I am well aware that I am on delicate ground, since many and various opinions have been expressed in regard to the nature of the remains here discovered, and particularly as to the form and appearance during life of the animals they represent. I may, perhaps, be permitted, in this connection, to say, what has often occurred to me, that the Dinosaurs seem to have been rather unfortunate, and to have suffered much from both their enemies and their friends. Many of them were destroyed and dismembered long ago by their natural enemies, but, more recently, their friends have done them further injustice in putting together their scattered remains, and restoring them to supposed life-like forms.

* Abstract of Paper read before Section C, British Association for the Advancement of Science, Ipswich, September 14, 1895.

You are all doubtless familiar with the story told by your witty countryman, George Lewes, in his life of Gœthe, of an international attempt to reconstruct the camel. To complete this task, the Englishman, it is said, travelled to distant lands, studied the animal in its native wilds, and then prepared his report; the Frenchman went to the museum in Paris, examined stuffed specimens and skeletons, and wrote his account; while the German remained in his study at home, meditated on the subject, and finally evolved his idea of the camel from his inner consciousness. Similar methods, but not on the same international lines, have been followed in the case of the Dinosaurs, and if some of those that have been restored could speak, whatever they might say about the prehistoric enemies that destroyed them, they would surely ask to be saved from their latter-day friends.

Seriously, I think justice has not been done to this remarkable group of reptiles in rehabilitating them for the benefit of the rising generation in science, and some of the attempts, I fear, have been so firmly implanted in text-book literature, that, like the oft-repeated myth of the "coral insect," the errors will pass down to the next century before being eradicated. The German method has sometimes been used by Anglo-Saxons, and with a success quite equal to that in the case of the camel. To take one instance familiar to you all, let me mention *Megalosaurus*, the first Dinosaur described, and also *Iguanodon*, an herbivorous colleague, on which it doubtless preyed. The first restoration of these two reptiles made them, as they were supposed to be in life, quadrupedal, or four-footed animals of forbidding aspect, and as such they have since haunted the visions of several generations, young and old, by night and by day. I have just made a pilgrimage to Sydenham to see with my own eyes these famous restorations, and, so far as I can judge, there is nothing like unto them in the heavens, or on the earth, or in the waters under the earth. We now know from good evidence that both *Megalosaurus* and *Iguanodon* were bipedal, and to represent them as creeping, except in their extreme youth, would be almost as incongruous as to do this by the genus *Homo*.

Lest it be supposed that I consider the Dinosaurs alone to have suffered from the attempts of their friends to restore them to life, I might recall to your remembrance the well-known figure in the text-books, of *Dinotherium*, reclining peacefully, with its feet and limbs concealed, for the simple reason that no one knew anything about them; or that other picture of the *Labyrinthodon* without a tail, deliberately making foot-prints upon the sands of time, while no such form has yet been discovered. I might refer to still more frightful examples of the dangers encountered by over-zealous historians of ancient life, but those given will suffice.

Restorations of European Dinosaurs.

The restorations of Dinosaurs I have now to present to this section are four in number, and represent some of the best-known European forms, types of the genera *Compsognathus*, *Scelidosaurus*, *Hypsilophodon*, and *Iguanodon*. These outline restorations have been prepared by me mainly for comparison with the corresponding American forms, but in part to insure, so far as the present opportunity will allow, a more comprehensive review of the whole group. The specimens restored are all of great interest in themselves, and of special importance when compared with their nearest American allies.

Compsognathus. (Plate V.)

The first restoration, that of *Compsognathus longipes*, Wagner, 1861, shown natural size in the diagram (Plate V), is believed to represent fairly well the general form and natural position, when alive, of this diminutive carnivorous Dinosaur, that lived during the Jurassic period. The basis for this restoration is (1) a careful study of the type specimen itself, made by me in Munich, in 1881; (2) an accurate cast of this specimen, sent to me by Prof. von Zittel; and (3) a careful drawing of the original made by Krapf, in 1887. The original description and figure of Wagner (Bavarian Academy of Sciences, 1861) and those of later authors have also been used for some of the details. No restoration of the skeleton of this unique Dinosaur has hitherto been attempted.*

Compsognathus has been studied by so many anatomists of repute since its discovery, that any attempt to restore the skeleton to a natural position will be scrutinized from various points of view. My interest in this unique specimen led me long ago to examine it with care, and I have since made a minute study of it, as related elsewhere, not merely to ascertain all I could about its anatomy, but also to learn, if possible, what its relations were to another diminutive form, *Hallopus*, from a lower horizon in America, which has been asserted to be a near ally. Both are carnivorous Dinosaurs, probably, but certainly on quite different lines of descent.

The only previous attempt to restore this remarkable Dinosaur was by Huxley, when in America, in 1876. He made a rapid sketch from the Wagner figure, and I had this enlarged for his New York lecture. This sketch, reproduced on the diagram before you (figure 1), represents the animal sitting down, a position which such Dinosaurs occasionally assumed, as shown by the footprints in the Connecticut Valley, which Huxley examined in place at several localities with great interest.

* The remains of the embryo within the skeleton of *Compsognathus*, first detected by me in 1881, while examining the type specimen, is not represented in the present restoration. This unique fossil affords the only known evidence that Dinosaurs were viviparous.

The great majority of Dinosaurian footprints preserved were evidently made during ordinary locomotion, although some series show evidence of more rapid movement. All those referred to carnivorous Dinosaurs are bipedal, and this is true of the footprints of many herbivorous forms.

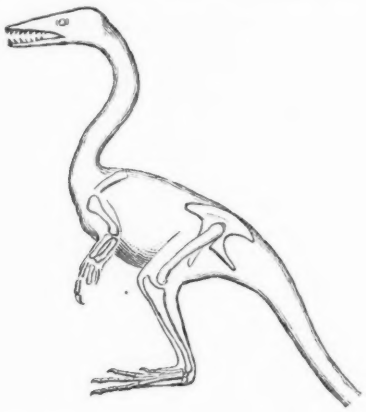


FIGURE 1.—Sketch of *Compsognathus longipes*, Wagner. One-seventh natural size. (After Huxley.)

In the present restoration of *Compsognathus* (Plate V), I have tried to represent the animal as walking, in a characteristic position true to life.

Scelidosaurus. (Plate VI.)

The second of these restorations is that of *Scelidosaurus Harrisonii*, of Owen, shown natural size in the diagram. This reptile was an herbivorous Dinosaur of moderate size, related to *Stegosaurus*, and was its predecessor from a lower geological horizon in England. This restoration is essentially based upon the original description and figures of Owen (Palæontographical Society, 1861). These have been supplemented by my own notes and sketches, made during examinations of the type specimen, now in the British Museum.

Scelidosaurus is a near relative, as it were, of one of our American forms, *Stegosaurus*, now represented by so many specimens that we know the skull, skeleton, and dermal armor, with much certainty. The English form known as *Omosaurus* is still more nearly allied to *Stegosaurus*, perhaps identical.

A restoration of the skeleton of *Scelidosaurus*, by Dr. Henry Woodward, will be found in the British Museum Guide to Geology and Palæontology, 1890, p. 19. The missing parts are restored from *Iguanodon*, and the animal is represented as bipedal, as in that genus.

In the present outline restoration of *Scelidosaurus*, I have endeavored merely to place on record my idea of the form and position of the skeleton, when the animal was alive, based on the remains I have myself examined. In case of doubt, as, for example, in regard to the front of the skull, which is wanting in the type specimen, I have used a dotted outline, based on the nearest allied form. Of the dermal armor, only the row of plates best known is indicated. The position chosen in this figure (Plate VI) is one that would be assumed by the animal in walking on all four feet, and this I believe to have been its natural mode of progression.

Hypsilophodon. (Plate VII.)

The third of these restorations, that of *Hypsilophodon Foxii*, Huxley, 1870, given in outline, natural size, in the diagram, has been made with much care, partly from the type specimen, and in part from other material mostly now in the British Museum. The figures and description by the late Dr. Hulke* were of special value, although my own conclusions as to the natural position of the animal when alive do not coincide with those of my honored friend, who did so much to make this genus of Dinosaurs, and others, known to Science. The restoration by Dr. Hulke is shown in another diagram.

In the case of *Hypsilophodon*, a number of specimens are available instead of only one. This makes the problem of restoration in itself a simpler matter than in *Scelidosaurus*. Moreover, we have in America a closely allied form, *Laosaurus*, of which several species are known. A study of the genus *Laosaurus*, and the restoration of one species given on the plate before you, will clear up several points long in doubt.

Huxley and Hulke both shed much light on this interesting genus, *Hypsilophodon*, indeed, on many of the *Dinosauria*. The mystery of the Dinosaurian pelvis, which baffled Cuvier, Mantell, and Owen, was mainly solved by them, the ilium and ischium by Huxley, and the pubis by Hulke. The more perfect American specimens have demonstrated the correctness of nearly all their conclusions.

Iguanodon. (Plate VIII.)

The fourth restoration here given, that of *Iguanodon Bernissartensis*, Boulenger, 1881, one-fifth natural size, has been made in outline for comparison with American forms. It is based mainly on photographs of the well-known Belgian specimens, the originals of which I have studied with considerable care during several visits to Brussels. The descriptions and figures of Dollo† have also been used in the preparation of this restoration. A few changes only have been introduced in the accompanying plate, based mainly upon a study of the original specimens.

* Philosophical Transactions, 1882. † Bulletin Royal Museum of Belgium, 1882–'88.

Besides the four genera here represented, no other European Dinosaurs at present known are sufficiently well preserved to admit of accurate restorations of the skeleton. This is true, moreover, of the Dinosaurian remains from other parts of the world outside of North America.

To present a comprehensive view of the Dinosaurs, so far as now known, I have prepared the plate here shown, which gives restorations of the twelve best-known types, as I have thus far been able to reconstruct them.* Of these twelve forms, eight are from America: *Anchisaurus*, a small carnivorous type from the Trias; *Brontosaurus*, *Camptosaurus*, *Laosaurus*, and *Stegosaurus*, all herbivorous, and the carnivorous *Ceratosaurus*, from the Jurassic; with *Claosaurus* and *Triceratops*, herbivores from the Cretaceous. These American forms, with the four from Europe already shown to you, complete the series represented on this chart. They form an instructive group of the remarkable Reptiles known as *Dinosauria*.

The geological positions of *Compsognathus* and of *Scelidosaurus* are fully determined, but that of *Hypsilophodon* and *Iguanodon* is not so clear. The latter are found in the so-called Wealden, but just what the Wealden is I have not been able to determine from the authorities I have consulted. The Cretaceous age of these deposits appears to be taken for granted here, but the evidence as it now stands seems to me to point rather to the upper Jurassic as their true position. If I should find the vertebrate fossils now known from your Wealden in the Rocky Mountains, where I have collected many corresponding forms, I should certainly call them Jurassic, and have good reason for so doing. Moreover, after visiting typical Wealden localities here and on the continent, I can still see no reason for doing otherwise so far as the vertebrate fossils are concerned, and in such fresh-water deposits their evidence should be conclusive. I have already called attention to this question of the age of the Wealden, and do so again, as I believe it worthy of a careful reconsideration by English geologists.

EXPLANATION OF PLATES.

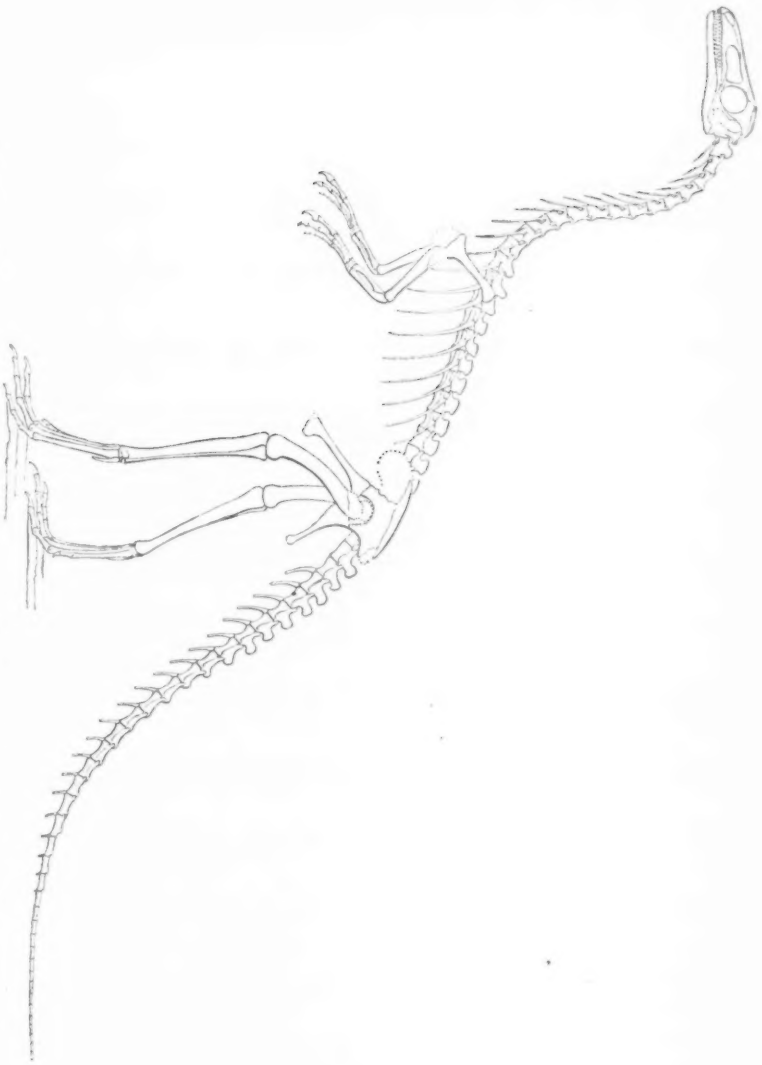
PLATE V.—Outline restoration of the skeleton of *Compsognathus longipes*, Wagner. One-fourth natural size. Jurassic, Bavaria.

PLATE VI.—Outline restoration of the skeleton of *Scelidosaurus Harrisonii*, Owen. One-eighteenth natural size. Jurassic, England.

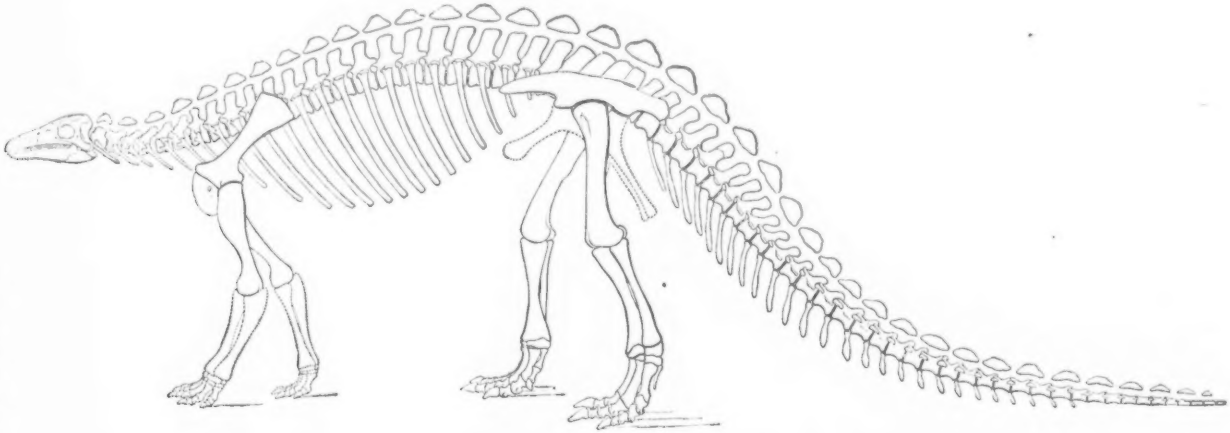
PLATE VII.—Outline restoration of the skeleton of *Hypsilophodon Foxii*, Huxley. One-eighth natural size. Wealden, England.

PLATE VIII.—Outline restoration of the skeleton of *Iguanodon Bernissartensis*, Boulenger. One-fortieth natural size. Wealden, Belgium.

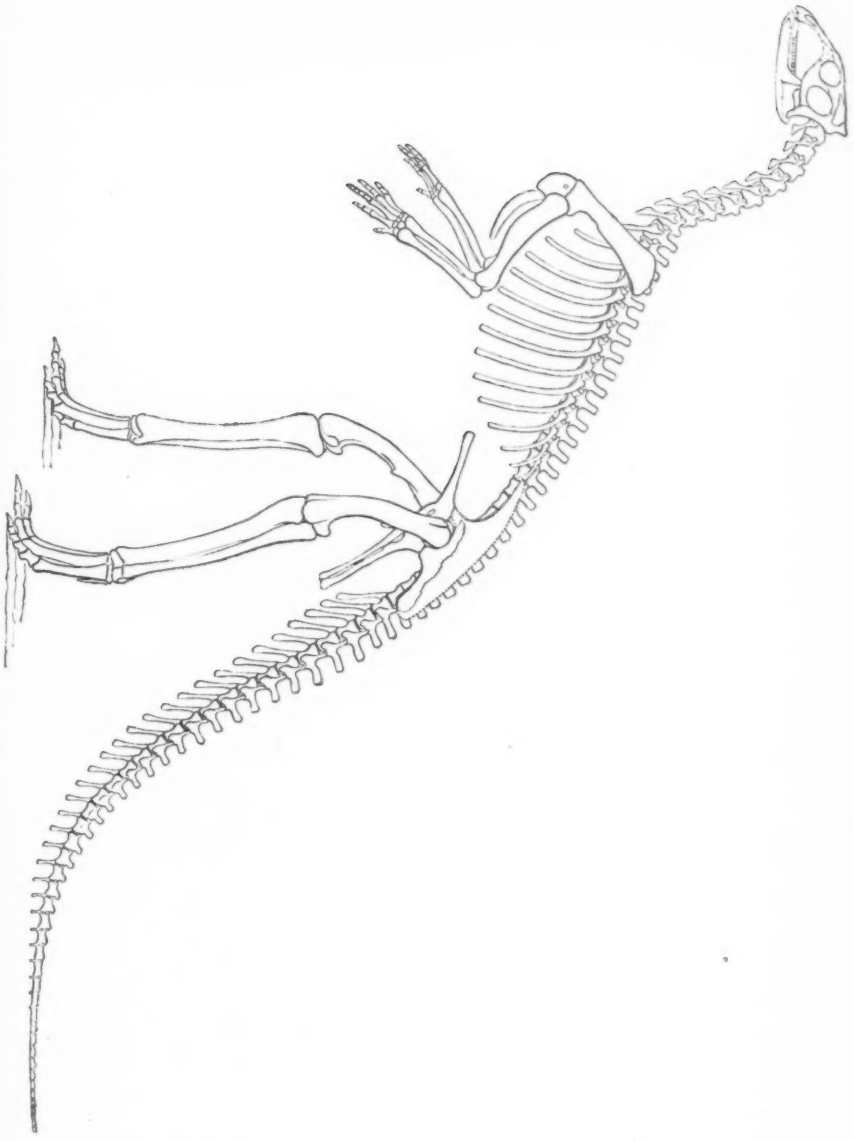
* A copy of this plate will appear in the next number of this Journal.



Restoration of COMPSOGNATHUS LONGIPES, Wagner. One-fourth natural size. Jurassic, Bavaria.



Restoration of SCELIDOSAURUS HARRISONII, Owen. One-eighteenth natural size. Jurassic, England.



Restoration of IGUANODON BERNISSARTENSIS. Boulenger. One-fortieth natural size. Wealden, Belgium.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The refractivity and viscosity of Argon and Helium.*—At the recent meeting of the British Association, Lord Rayleigh read a paper on the refractivity and viscosity of these gases. He described how, by means of an electric arc, kept up for several weeks in a mixture of oxygen and atmospheric nitrogen, he finally obtained more than a litre of argon at atmospheric pressure. This proved to have the same density as the specimen obtained by the magnesium method. The refractive index was measured by the interference method of Fizeau, the two beams being separated by slits in front of the lens nearest the eyepiece. The latter was constructed of cylindrical lenses. To avoid the use of cross-wires, the tubes containing the gases under comparison were arranged so as not to occupy the whole field of view, some light passing parallel to and outside them; two sets of fringes were thus obtained, which could be brought to coincidence by varying the pressure of either gas. Adjustments were made for several pressures, one of the tubes always containing air. The values of the refractivity ($\mu-1$) were, for argon 0·961, and for helium 0·146, that of air being taken as unity. The viscosity of each gas was measured by its rate of flow through a capillary tube, the results being (air = 1) argon 1·21, helium 0·96. Lord Rayleigh mentioned that a sample of nitrogen collected from a Bath spring, where it bubbles out along with the water, gave the D_3 line of helium. Dr. Gladstone showed that the results of these experiments assign to argon the atomic weight 20, its specific refractive energy being intermediate between those of fluorine and sodium, but not between those of potassium and calcium.—*Nature*, lii, 533.

2. *On the compound nature of the gas from Cleveite.*—In the paper on the constituents of the gas from cleveite, alluded to in the last number, C. Runge and F. Paschen show that it must be regarded as made up of two and only two constituents. One of these, to which the bright yellow double line belongs, it is proposed to call helium,—this has the stronger spectrum; the other constituent as yet remains unnamed. After stating this conclusion and the theoretical grounds upon which it is based, the authors go on to say:

We have confirmed this rather hypothetical conclusion by the following experiment. The connection leading from our supply of cleveite gas to the vacuum tube contained a side branch parting from it and joining it again. There were stopcocks on either side of the side branch, and a third one in the side branch. In the main tube between the ends of the side branch a plug of asbestos was tightly inserted. To prepare the vacuum tube only the tap leading to the supply was closed, the whole space up to

this tap being carefully evacuated. Now the side branch was closed, and the tap leading to the supply was opened. Then we observed that the light of the electric discharge in the vacuum tube was at first greenish, and after a while grew yellow. By cutting off the current of gas after a sufficiently short time, we succeeded in making a vacuum tube which remained greenish. On examining it in a small spectroscope with which we could overlook the whole spectrum, we found that the intensities of the lines had changed. The yellow line was scarcely as bright as the green line 5016, and the red line 7065 had apparently decreased relatively to 7282 and 6678, although it was still stronger than 7282. The two lines that had decreased in intensity belong to the second set of series, while the others are members of the first set. The other visual lines of the second set could not very well be examined because they are more in the violet part.

This observation confirms our spectroscopic result. The gas in cleveite may be taken to be a mixture of two gases of different density, of which the lighter one is more rapidly transmitted through the plug of asbestos. There is, however, the objection to be raised, that in the green tube the pressure is less, and that the difference of intensities is due to the pressure being different. This must be further inquired into.

We were not satisfied with the visual observation of the change of intensities in our green tube, but thought it desirable to test the conclusion by the bolometric measurement of the two lines that we have discovered in the ultra-red part of the spectrum. If we were right, the ultra-red line of smaller wave-length, which belongs to the second set of series, ought to have decreased in intensity relatively to the other ultra-red line. This we found to be so indeed. In the yellow tubes the intensity of the smaller wave-length was to that of the other on an average as 3 to 1, while in the green tubes it was as 1·8 to 1. This confirmation we consider the more valuable as it does not depend on any estimation which may be biassed by the personal opinion of the observer, but is based on an objective numerical determination.

Another confirmation may be gathered from the spectrum of the sun's limb and that of several stars. Let us confine our attention to the six strongest lines in the visible part of the spectrum :

7066, 6678, 5876, 5016, 4922, 4472.

The first, third, and sixth belong to the second set of series; the second, fourth and fifth to the first set. These six lines have all been observed in the spectrum of the sun's limb, as Norman Lockyer and Deslandres have pointed out. Now, according to their appearance in the spectrum of the sun's limb, they may be classed in two groups, one group being always present, the other group being sometimes present. C. A. Young long ago called attention to the difference in the frequency of appearance of the chromospheric lines. He has given them frequency numbers,

roughly estimating the percentage of frequency with which the lines were seen during the six weeks of observation at Sherman in the summer of 1872. According to Young, 7066, 5876, 4472 have the frequency number 100, while 6678, 5016, 4922 have the numbers 25, 30, 30, showing that one of the two constituents was always present, while the other was only seen about once in every four cases.

The lines of both constituents have been observed in the spectra of a considerable number of stars β, δ, ε, ζ, γ, Orionis, α Virginis, β Persei, β Tauri, η Ursæ majoris, β Lyræ. In the spectrum of β Lyræ, thirteen lines have been identified with certainty. But the most interesting case in point is the spectrum of Nova Aurigæ, that wonderful star whose sudden appearance was announced to astronomers in 1892 by an anonymous postcard. In the spectrum of Nova Aurigæ the two lines 5016 and 4922 were very strong, while 4472 was weak and 5876 has only been seen by Dr. Huggins, we believe only on one occasion, and appears to have been very weak. Now 5016 and 4922 belong to the lighter constituent, and are together with 6678 the strongest lines in the visible part of the spectrum; while 5876 and 4472 are the strongest lines of the other constituent in the visible part of the spectrum. In Nova Aurigæ, therefore, the lighter constituent gave a much brighter spectrum than helium proper. But there may here be raised an objection, which indeed we do not know how to refute. Why has the line 6678 not been observed? It is a pity that the red part of the spectrum cannot be more easily photographed. Nova Aurigæ has now become very weak, and besides the spectrum is quite altered, so that we shall never know whether the red line 6678 was really absent or has only escaped notice.

From the fact that the second set of series is on the whole situated more to the refrangible part of the spectrum, one may, independently of the diffusion experiment, conclude that the element corresponding to the second set is the heavier of the two. In the spectra of chemically related elements like Li, Na, K, Rb, Cs, or Mg, Ca, Sr, or Zn, Cd, Hg, the series shift to the less refrangible side with increasing atomic weight. But it appears that in the spectra of elements following each other in the order of their atomic weights in a row of the periodic system like

Na, Mg, Al;
K, Ca;
Cu, Zn;
Rb, Sr;
Ag, Cd, In;

the series shift the opposite way, so that the spectrum of the element of greater atomic weight is as a whole situated further to the more refrangible side. Now in our case the density of the gas has been determined by Langlet (published by Cleve) and by Ramsay to be about double the density of hydrogen. Assuming

the atomic weights of the two constituents to be between that of lithium and that of hydrogen, they would both belong to the same row of the periodic system, and therefore the more refrangible set of series would correspond to the greater atomic weight.

For convenience of reference all the observed lines are given in the following table, the wave-lengths being abridged to tenth-metres.

Lighter Constituent.

Principal series.	First subordinate series.	Second-subordinate series.
20400	6678	7282
5016	4922	5048
3965	4388	4438
3614	4144	4169
3448	4009	4024
3355	3927	3936
3297	3872	3878
3258	3834	3838
3231	3806	3808
3213	3785	

Heavier Constituent (*Helium proper*).

	Double lines.	Double lines.
11220	5876	7066
3889	4472	4713
3188	4026	4121
2945	3820	3868
2829	3705	3733
2764	3634	3652
2723	3587	3599
2696	3555	3563
2677	3531	3537
	3513	3517
	3499	3503
	3488	3491
	3479	3482
	3472	
	3466	
	3461	

—*Nature*, lii, 521.

3. *On the specific refraction of Argon.*—Dr. Gladstone read a paper before the British Association on specific refraction and the periodic law, with special reference to argon and other elements. In former years he had shown that the specific refractive energies of the elements in general were, to a certain extent, a periodic function of their atomic weights. With regard to argon, the specific refractive energy of argon gas as reckoned by Lord Rayleigh's data is 0·159. At the suggestion of Deeley, the bearing of

this result on the atomic weight of argon was considered. If the atomic weight be 19·94, the molecular refraction will be 3·15. This figure is almost identical with that belonging to oxygen and nitrogen gas, and differs considerably from that of calcium, which has a molecular refraction of 10·0 and a specific refractive energy of 0·248. These facts tend to suggest an atomic weight of 20 for argon, and to place it in the vicinity of the alkali metals.—*Nature*, lii, 537.

4. *Color Photography.*—Zenker, Lehrbuch der Photochromie, Berlin, 1868, explained the phenomena of the colors produced in sensitized media by the hypothesis of the working of stationary light waves. Objections, however, to this hypothesis were raised by Schultz-Sellack (Pogg. Ann., cxliii, p. 449, 1871). Lippmann (Comptes Rendus, cxii, 1891), however, showed the possibility of employing stationary waves in color photography, and his results apparently sustained the conclusions of Zenker. Schultz-Sellack, in support of his position, showed that powdered substances had served for the reproduction of color. For instance Seebeck used paper moistened with a gray preparation of chloride of silver. This use of powder has no connection with transparent layers formed by Becquerel on good reflecting surfaces, such as silver plates which have been covered with a chloride of silver by electrolysis. The recent researches, however, of Carey Lea throw doubt upon the hypothesis of Zenker, for he shows that the colors of chloride of silver can be formed in the dark by purely chemical processes. H. Krone also, in his treatise on the representation of natural colors by photographie (Verlag der deutschen Photographenzeitung, p. 43, 1894) asserts that the Poitevin method, which consists in bathing paper in different solutions, rests upon purely chemical grounds and is radically different from that of Lippmann's. Krone maintains that our present incomplete knowledge of the production of color in photography rests upon Zenker's theory. Otto Wiener undertakes in an exhaustive article to settle the question: "Were the colors obtained by the early workers in this subject due to interference of waves of light or to absorption?" His experiments show that Becquerel's results depend upon interference, that in the images obtained by Seebeck and Poitevin no color change enters. They are obtained from the color of the particles, and Zenker's hypothesis does not apply to them. The color of the particles, body color, *körperfarbe*, also enters into Becquerel's results. Wiener addresses himself to the question why certain color stuffs give back the color of the illumination, and finds the explanation that the color stuff does not absorb the light of its own color but reflects it, while the other colors are absorbed by the stuff and broken up. It is therefore possible that colored illumination in suitable stuffs can awaken similar colors in color particles. He calls such material color-susceptible, *farbenempfängliche*. This possibility and the knowledge of its conditions leads to the foundation of a new art of color photography, which can be termed body color photography,

and the hope appears to be well-founded that the results obtained by this art will exceed those previously obtained. The giving back of the color can be termed color adaptation, *farbenanpassung*, since it consists in letting free the color material, which best resists the breaking-up influence of the illuminating color. The author concludes with some references to observations on the color of animals, by Darwin, Poulton, Roux and others, which illustrate the influence of color particles, according to his theory.—*Ann. der Physik und Chemie*, No. 6, 1895, pp. 226–281. J. T.

5. *The Electric Aureole: and Stratifications in the Electric arc and in discharges in rarified gases.*—Many observers have noticed the peculiar forked flame discharges produced in the discharge from electrodes of the secondary circuit of a suitable transformer. Spottiswode was the first to excite a Ruhmkorf coil by an alternating dynamo, and thus to lead the way to a study of the relation between this forked flame-like discharge and the ordinary voltaic arc. LEHMANN has made an exhaustive study of this phenomena, both in the air and in various vessels containing rarified air and gases. He shows that the exchanges of heat between the walls of the vessels and the layers of rarified air must be considered in studying the phenomena of stratification. His paper contains many illustrations of the aureoles formed and of the isothermal surfaces about and between the electrodes, and a discussion of the influence of partial discharges on the phenomenon of stratification. His investigation has a bearing upon certain phases of the aurora borealis.— *Ann. der Physik und Chemie*, No. 6, 1895, pp. 361–388. J. T.

6. *Magnetism of Asbestos.*—Faraday placed asbestos in the list of weak magnetic bodies, but recent observers have discovered that certain varieties of this mineral are strongly magnetic. Swinton, in the Electrical Review, 34, No. 880, Oct. 5, 1894, has called attention to this property of asbestos, and BLEEKRODE shows that a gray variety exhibits strong magnetism even in comparatively weak magnetic fields. He points out that this substance should not be used as an insulating material in magnetic instruments.—*Ann. der Physik und Chemie*, No. 6, 1895, p. 398. J. T.

7. *Electric refraction of Liquids.*—P. DRUDE, using a modification of Blondlot's apparatus for exciting powerful electric oscillations, has obtained for electric waves in water a refractive index of 9 and a specific inductive capacity equal to 81.—*Ann. der Physik und Chemie*, No. 8, 1895, p. 633–655. J. T.

8. *Double refraction of electric waves in ice.*—V. BIERNACKI uses one of Lodge's coherers in connection with parabolic mirrors of small size, 45^{cm} in height, aperture 30^{cm} and focal length 3^{cm}. The introduction of a thick slab of ice between the two crossed mirrors with its axis 45° to both the focal lines exhibits the double refraction of the ice.—*Ann. der Physik und Chemie*, No. 8, 1895, p. 599–603. J. T.

9. *Double Refraction of Electric Waves.*—Peter Lebedew has succeeded in reducing the size of Hertz's apparatus for exhibiting the reflection-polarization and refraction of electric waves, so that he could work with waves only a fraction of a centimeter in length ($\lambda = 0{\cdot}6^{cm}$) and with prisms scarcely more than a centimeter in height. The arrangement of the mirrors and the prisms is the same as that of the observing telescopes and prism in the case of the optical spectrometer. A prism of sulphur $1{\cdot}8^{cm}$ high, $1{\cdot}3^{cm}$ broad with a refracting angle of 25° was used. The values of the indices of refraction obtained were $N_1 = 2{\cdot}2$ $N_2 = 2{\cdot}0$ for the two directions in which Boltzman had measured the dielectric constants of sulphur. The square roots of the dielectric constants are, 2·18 and 1·95, and Maxwell's law therefore holds within the limits of error of observation. Instead of a spark micrometer, Lebedew employed a thermal junction of iron and constantan. His paper contains illustrations and descriptions of his apparatus.—*Ann. der Physik und Chemie*, No. 9, 1895, pp. 1–17. J. T.

II. Geology and Mineralogy.

1. *On the Temperature Variation of the Thermal Conductivity of Rocks;* by Lord Kelvin and J. R. Erskine Murray.

(1.) The experiments described in this communication were undertaken for the purpose of finding temperature variation of thermal conductivity of some of the more important rocks of the earth's crust.

(2.) The method which we adopted was to measure, by aid of thermoelectric junctions, the temperatures at different points of a flux line in a solid, kept unequally heated by sources (positive and negative) applied to its surface, and maintained uniform for a sufficiently long time to cause the temperature to be as nearly constant at every point as we could arrange for. The shapes of the solid and the thermal sources were arranged to cause the flux lines to be, as nearly as possible, parallel straight lines; so that, according to Fourier's elementary theory and definition of thermal conductivity, we should have

$$\frac{k(\mathrm{M,\ B})}{k(\mathrm{T,\ M})} = \frac{[v(\mathrm{M}) - v(\mathrm{T})] \div \mathrm{MT}}{[v(\mathrm{B}) - v(\mathrm{M})] \div \mathrm{BM}},$$

where T, M, B denote three points in a stream line (respectively next to the top, at the middle, and next to the bottom in the slabs and columns which we used); $v(\mathrm{T})$, $v(\mathrm{M})$, $v(\mathrm{B})$ denote the steady temperatures at these points; and $k(\mathrm{T,\ M})$, $k(\mathrm{M,\ B})$, the mean conductivities between T and M, and between M and B respectively.

(3.) The rock experimented on in each case consisted of two equal and similar rectangular pieces, pressed with similar faces together. In one of these faces three straight parallel groves are cut, just deep enough to allow the thermoelectric wires and junc-

tions to be embedded in them, and no wider than to admit the wires and junctions. Thus, when the two pieces of rock are pressed together, and when heat is so applied that the flux lines are parallel to the faces of the two parts, we had the same result, so far as the thermal conduction is concerned, as if we had taken a single slab of the same size as the two together, with long fine perforations to receive the electric junctions. The compound slab was placed with the perforations horizontal, and their plane vertical. Its lower side, when thus placed, was immersed under a bath of tin, kept melted by a lamp below it. Its upper side was flooded over with mercury in our later experiments (pars. 6, 7, 8), as in Hopkins's experiments on the thermal conductivity of rock. Heat was carried off from the mercury by a measured quantity of cold water poured upon it once a minute, allowed to remain till the end of a minute, and then drawn off and immediately replaced by another equal quantity of cold water. The chief difficulty in respect to steadiness of temperature was the keeping of the gas lamp below the bath of melted tin uniform. If more experiments are to be made on the same plan, whether rocks or metals, or other solids, it will, no doubt, be advisable to use an automatically regulated gas flame, keeping the temperature of the hot bath in which the lower face of the slab or column is immersed at as nearly constant a temperature as possible, and to arrange for a perfectly steady flow of cold water to carry away heat from the upper surface of the mercury resting on the upper side of the slab or column. It will also be advisable to avoid the complication of having the slab or column in two parts, when the material and the dimensions of the solid allow fine perforations to be bored through it, instead of grooves, which we found more readily made with the appliances available to us.

(4.) Our first experiments were made on a slate slab, 25 cm. square and 5 cm. thick, in two halves, pressed together, each 25 cm. by 12·5, and 5 cm. thick. One of these parts cracked with a loud noise in an early experiment, with the lower face of the composite square resting on an iron plate heated by a powerful gas burner, and the upper face kept cool by ice in a metal vessel resting upon it. The experiment indicated, very decidedly, less conductivity in the hotter part below the middle than in the cooler part above the middle of the composite square slab. We supposed this might possibly be due to the crack, which we found to be horizontal and below the middle, and to be complete across the whole area of $12\frac{1}{2}$ cm. by 5, across which the heat was conducted in that part of the composite slab; and to give rise to palpably imperfect fitting together of the solid above and below it. We therefore repeated the experiment with the composite slab turned upside down, so as to bring the crack in one half of it now to be above the middle, instead of below the middle, as at first. We still found for the composite slab less conductivity in the hot part below the middle than in the cool part above the middle. We inferred that, in respect to thermal conduction

through slate across the natural cleavage planes, the thermal conductivity diminishes with increase of temperature.

(5.) We next tried a composite square slab of sandstone of the same dimensions as the slate, and we found for it also decisive proof of diminution of thermal conductivity with increase of temperature. We were not troubled by any cracking of the sandstone, with its upper side kept cool by an ice-cold metal plate resting on it, and its lower side heated to probably as much as 300° or 400° C.

(6.) After that we made a composite piece, of two small slate columns, each 3·5 cm. square and 6·2 cm. high, with natural cleavage planes vertical, pressed together with thermoelectric junctions as before; but with appliances (par. 10 below) for preventing loss or gain of heat across the vertical sides, which the smaller horizontal dimensions (7 cm., 3·5 cm.) might require, but which were manifestly unnecessary with the larger horizontal dimensions (25 cm., 25 cm.) of the slabs of slate and sandstone used in our former experiments. The thermal flux lines in the former experiments on slate were perpendicular to the natural cleavage planes, but now, with the thermal flux lines parallel to the cleavage planes, we still find the same result, smaller thermal conductivity at the higher temperatures. Numerical results will be stated in par. 12 below.

(7.) Our last experiments were made on a composite piece of Aberdeen granite, made up of two columns, each 6 cm. high and 7·6 cm. square, pressed together, with appliances similar to those described in par. 6; and, as in all our previous experiments on slate and sandstone, we found less thermal conductivity at higher temperatures. The numerical results will be given in par. 12 below.

(8.) The accompanying diagram [here omitted] represents the thermal appliances and thermoelectric arrangement of pars. 6, 7. The columns of slate or granite were placed on supports in a bath of melted tin with about 0·2 cm. of their lower ends immersed. The top of each column was kept cool by mercury, and water changed once a minute, as described in par. 3 above, contained in a tank having the top of the stone column for its bottom and completed by four vertical metal walls fitted into grooves in the stone and made tight against wet mercury by marine glue.

(9.) The temperatures, $v(B)$, $v(M)$, $v(T)$ of B, M, T, the hot, intermediate, and cool points in the stone, were determined by equalizing to them successively the temperature of the mercury thermometer placed in the oil-tank, by aid of thermoelectric circuits and a galvanometer used to test equality of temperature by nullity of current through its coil when placed in the proper circuit, all as shown in the diagram. The steadiness of temperature in the stone was tested by keeping the temperature of the thermometer constant, and observing the galvanometer reading for current when the junction in the oil-tank and one or other of the three junctions in the stone were placed in circuit. We also

helped ourselves to attaining constancy of temperature in the stone by observing the current through the galvanometer, due to differences of temperature between any two of the three junctions B, M, T placed in circuit with it.

(10.) We made many experiments to test what appliances might be necessary to secure against gain or loss of heat by the stone across its vertical faces, and found that *kieselguhr*, loosely packed round the columns and contained by a metal case surrounding them at a distance of 2 cm. or 3 cm., prevented any appreciable disturbance due to this cause. This allowed us to feel sure that the thermal flux lines through the stone were very approximately parallel straight lines on all sides of the central line BMT.

(11.) The thermometer which we used was one of Cassella's (No. 64,168) with Kew certificate (No. 48,471) for temperature from 0° to 100°, and for equality in volume of the divisions above 100°. We standardized it by comparison with the constant volume air thermometer* of Dr. Bottomley with the following result. This is satisfactory as showing that when the zero error is corrected the greatest error of the mercury thermometer, which is at 211° C., is only 0·3°.

Reading.		Correction to be subtracted from reading of mercury thermometer.
Air thermometer.	Mercury thermometer.	
°	°	
0	1·9	1·9
120·2	122·2	2·0
166·8	168·6	1·8
211·1	212·7	1·6
265·7	267·5	1·8

(12.) Each experiment on the slate and granite columns lasted about two hours from the first application of heat and cold; and we generally found that after the first hour we could keep the temperatures of the three junctions very nearly constant. Choosing a time of best constancy in our experiments on each of the two substances, slate and granite, we found the following results:

Slate: flux lines parallel to cleavage.

$$v(\mathrm{T}) = 50°{\cdot}2\ \mathrm{C.}$$
$$v(\mathrm{M}) = 123°{\cdot}3.$$
$$v(\mathrm{B}) = 202°{\cdot}3.$$

The distances between the junctions were BM = 2·57 cm. and MT = 2·6 cm. Hence the formula of par. 2,

$$\frac{k(\mathrm{M,\ B})}{k(\mathrm{T,\ M})} = \frac{73{\cdot}1 \div 2{\cdot}6}{79{\cdot}0 \div 2{\cdot}57} = \frac{28{\cdot}1}{30{\cdot}7} = 0{\cdot}91.$$

Aberdeen granite:

$$v(\mathrm{T}) = 81°{\cdot}1.$$
$$v(\mathrm{M}) = 145°{\cdot}6.$$
$$v(\mathrm{B}) = 214°{\cdot}6.$$

* Phil. Mag., August, 1888, and Edinb. Roy. Soc. Proc., January 6, 1888.

The distances between the junctions were BM = 1·9 cm. and MT = 2·0 cm.

$$\frac{k(\mathrm{MB})}{k(\mathrm{TM})} = \frac{64{\cdot}5 \div 2{\cdot}0}{69{\cdot}0 \div 1{\cdot}9} = \frac{32{\cdot}2}{36{\cdot}3} = 0{\cdot}88.$$

(13.) Thus we see, that for slate, with lines of flux parallel to cleavage planes, the mean conductivity in the range from 123° C. to 202° C. is 91 per cent of the mean conductivity in the range from 50° C. to 123° C., and for granite, the mean conductivity in the range from 145° C. to 214° C. is 88 per cent of the mean conductivity in the range from 81° C. to 145° C. The general plan of apparatus, described above, which we have used only for comparing the conductivities at different temperatures, will, we believe, be found readily applicable to the determination of conductivities in absolute measure.—*Proc. Roy. Soc.*, No. 349.

2. *United States Geological Survey: 14th Annual Report for 1892–'93;* by J. W. Powell, Director. Part I, Report of the Director, pp. 1–321. Part II, Accompanying papers, pp. 1–597. Plates i–lxxiv, figures 1–75. Washington, 1894.—This report of the annual progress of the work of the government survey contains more than the usual number of valuable contributions to geological science. The following is the list of accompanying papers, viz:

W. J. McGee: Potable waters of Eastern United States.
A. C. Peale: Natural mineral waters of the United States.
F. H. Newell: Results of stream measurement.
Whitman Cross: The Laccolitic mountain group of Colorado, Utah, and Arizona.
Waldemar Lindgren: The gold-silver veins of Ophir, California.
Arthur Keith: Geology of the Catoctin belt.
J. S. Diller: Tertiary revolution in the topography of the Pacific Coast.
H. W. Turner: The rocks of the Sierra Nevada.
Charles D. Walcott: Pre-Cambrian rocks of the Unkar terrane, grand cañon of the Colorado, Arizona; with notes on the petrographic character of the lavas, by Joseph Paxon Iddings.
T. Nelson Dale: On the structure of the ridge between the Taconic and Green Mountain ranges in Vermont; The structure of Monument Mountain in Great Barrington, Massachusetts.
Joseph D. Weeks: The Potomac and Roaring Creek coal fields in West Virginia.

The first three papers are of general economic value and are more or less directly connected with investigation of the hydrographic conditions of the various regions of the United States. Mr. Newell's paper on stream measurements is the fifth of a series of papers on the discharge of rivers, the other four having been published in the 10th, 11th, 12th and 13th annual reports; the first three of them in the sets of Irrigation survey reports.

Mr. Cross's paper is a valuable contribution to the petrography of intrusive rocks. "The object and plan of the discussion," the author defines to be twofold: "On the one hand it is desired to establish more clearly than has previously been attempted the various phases characteristic of the intrusion of a certain class of

igneous masses into the sedimentary complex; on the other hand, the rock type produced by the consolidation of these magmas has been found to have characteristics worthy of special note in the bearing upon the principles of petrography." The author has had not only his own investigation in the Colorado region, but the admirable work of Gilbert, Peale, Holmes, and others to furnish him with the facts necessary to a comprehensive discussion of the phenomena concerned.

Mr. Keith's paper is an exhaustive discussion of a typical piece of geological structure in the midst of the Appalachian region. "The Catoctin belt," the author states, "has shown itself to be an epitome of the leading events of geological history in the Appalachian region. It contains the earliest formations whose original character can be certified; it contains almost the latest known formations; and the record is unusually full, with the exception of the later Paleozoic rocks. Its structures embrace nearly every known type of deformation. It furnishes examples of every process of erosion, of topography derived from rocks of nearly every variety of composition, and of topography derived from all types of structure except the flat plateau type. In the recurrence of its main geographic features from pre-Cambrian time till the present day it furnishes a remarkable and unique example of the permanence of Continental form." In the paper the leading geological events which have left their impress on the region are traced and their effects recorded.

Mr. Diller's paper is another comprehensive study of the geological history of a region, that of Northern California, the borders of the Sacramento Valley, in the Klamath Mountains and the western slope of the Sierra Nevada. The author finds this region practically reduced to a baselevel condition during the early portion of the auriferous gravel period. "The mountain ranges were low, and the scenery was everywhere characterized by gentle flowing slopes. . . . The topographic revolution consisted in the development out of such conditions of the conspicuous mountain ranges of to-day. The northern end of the Sierra Nevada has since been raised at least 4,000 feet, and possibly as much as 7,000 feet, and a fault of over 3,000 feet developed along the eastern face of that portion of the range. The Klamath Mountains may in some portions have experienced at the same time an equal upheaval. From both sides the amount of uplift decreases rapidly toward the Sacramento Valley. In the initial part of this revolution the earlier auriferous gravels were found. The source of their material, of which, next to gold, quartz is the most important, was found in the thick deposit of residuary detritus which had accumulated upon the surface of the land during the baselevel period. The large mass of disintegrated rock substance rendered the loading of the streams so easy that when rejuvenated by orogenic movements they readily became overloaded and filled their ancient channels with auriferous gravels."

The two papers, by Messrs. Lindgren on the gold-silver veins of

Ophir and Weeks on coal-fields of West Virginia, have special mining interest; and the remaining papers are discussions of more local or special geological problems. In reading these papers it must be borne in mind that although issued in 1895, due to the tardy working of the Government printing office, they were completed and given to the director two years ago. An important new feature in the Report of the Director is the publication of synopses of the publications of the survey during the period 1892–'93. In the present case outlines of the contents are given of Monographs XVII, XVIII and XX and of the Bulletins 84, 85, 86, 90, 92, 93, 94, 95, 96, 98, 99 and 100. H. S. W.

3. *The gold fields of the Southern Appalachians.*—The report of GEORGE F. BECKER* on the gold fields of the Southern Appalachians, based upon investigations made in 1894, is issued as a separate brochure and contains a summary account of the gold-bearing regions of the Carolinas and Georgia, to which is added a digest of the geology of the gold deposits of the Maritime Provinces of British America and the Green Mountains, thus making a comprehensive sketch of the gold deposits of the Atlantic slope.

4. *Columnar sandstone.*—In an article "On the structure and composition of a Basalt from Bondi, New South Wales," by J. MILNE CURRAN, a beautiful figure, reproduced from a photograph, is given of columnar sandstone. The author states that "this structure was no doubt induced by the proximity of the igneous rock. Some of the sandstones, that were in contact with the molten basalt, show very little trace of metamorphism, while in other parts the same sandstones are rendered quartzose in texture and prismatic in structure." Although no statement is made of the size of the columns, from comparison with other objects in the figure, it is estimated that the columns are at least twenty feet in length and two to three feet in diameter.—*Jour. Roy. Soc. N. S. W.*, vol. xxviii, p. 221, and pl. ix.

5. *Petrology for Students;* by A. HARKER. 12°, 306 pp. Figs. in text. Cambridge University Press, 1895.—This little volume supplies a long-felt want. There are many geologists and geological students who, while not intending to make petrology their chief aim, yet desire sufficient knowledge of the subject to enable them to understand it and to comprehend in a general way the most recent results in this field of science. To these the appearance of the present work will prove most acceptable. The use of the microscope and the study of rocks in thin sections is of course assumed, as indeed it must be to achieve any results in this field. While many minor details are, from the scope of the work, necessarily omitted, the main features of the science are comprehensively and broadly, though simply handled, and a careful

* Reconnaissance of the gold fields of the Southern Appalachians, by George F. Becker. Extract from 16th Ann Rept. of the Director, U. S. Geol. Survey, 1894–95. Part II, Min. Resources of U. S. Calendar year 1894, pp. 1–85. Washington, 1895.

study of the work will give an excellent grounding in the science. We note that the author, for purposes of classification, divides the igneous rocks into *plutonic*, *intrusive* and *volcanic*, a method that (with some disadvantages) has much to commend it. L. V. P.

6. *Introduction to the study of Rocks;* by L. FLETCHER. 118 pp. 8vo, 1895. (British Museum of Nat. History, Mineral Dept.)—This little work is designed chiefly as a guide to the study of the rock collections in the British Museum. The general principles of petrology are clearly and compactly stated, though in an elementary manner, in keeping with the plan of the work. It should prove of service to the general public visiting the museum and may well serve as a model guide-book for similar institutions elsewhere. L. V. P.

7. *Calaverite from Cripple Creek, Colorado;* correction by W. F. HILLEBRAND. (Communicated.)—In my paper on calaverite from Cripple Creek, Colorado, published in the August number of this Journal, I referred to papers by F. C. Knight and by Richard Pearce in the Proceedings of the Colorado Scientific Society for 1894. My information as to their contents had to be obtained at second hand. Now that I have had opportunity to read those papers I find to my great regret that I have unintentionally done the gentlemen an injustice in failing to give them further credit. Mr. Knight identified calaverite by analysis and showed the iron-tellurium oxidation product to be a ferric tellurite. My work was therefore but an elaborate confirmation of his prior identification of calaverite. Mr. Pearce is confident that sylvanite is a constituent of portions at least of the Cripple Creek ores, and his opinion is entitled to great consideration. While my paper in no way denies the possible existence of a telluride richer in silver than calaverite, it might be inferred that I attributed no great weight to Mr. Pearce's evidence on this point.

8. *Minerals from New South Wales;* Professor A. LIVERSIDGE has recently announced the discovery of the rare minerals *boleite* and *nantokite* at the Broken Hill silver mine in New South Wales. The former occurs in interpenetrating cubes, 4 to 7^{mm} on the edge, of an indigo-blue color; these are implanted upon or imbedded in a matrix of hematite and quartz; hardness, 3·5; specific gravity 5·02. An analysis by Carmichael and Armstrong gave:

Cl	Pb	Cu	Ag	O(calc.)	H_2O(calc.)
13·50	47·20	19 20	8·25	[6·10]	5 44

The amount of water found by Liversidge in an independent trial was 6·39, but this is probably too high. The analysis quoted agrees closely with those of the original boleite given by Mallard and Cumenge. The *nantokite* occurs in pale sea-green particles, apparently crystals but indistinct and with a slightly effloresced surface; on exposure the color becomes darker, and the surface opaque and powdery; hardness 2·5; specific gravity 4·7. An analysis by Carmichael and Armstrong gave:

Cu 64·28 Cl 35·92 = 100·20

This corresponds to Cu_2Cl_2 the composition of the original nantokite from Chili.—*Proc. Roy. Soc. N. S. Wales*, vol. xxviii.

9. *A contribution to the Mineralogy of Wisconsin;* by W. H. HOBBS. Bulletin of the University of Wisconsin Science Series, vol. i, No. 4, pp. 109–156, pl. 4–8. Madison, 1895.—Professor Hobbs has given in this bulletin an account of some minerals from Wisconsin, especially of the species calcite, galena, cerussite, sphalerite, etc., found in cavities in the Galena limestone in the southern part of the state. A number of new forms are noted, as on sphalerite, calcite, cerussite and azurite. Some interesting notes are added in regard to the diamonds found in the glacial drift of Wisconsin; these include three large stones (16, $3\frac{2}{32}$, $21\frac{1}{4}$ carats) and a number of small ones.

10. *Tabellarische Uebersicht der einfachen Formen der 32 krystallographischen Symmetriegruppen* zusammengestellt und gezeichnet von Dr. E. A. WÜLFING. Stuttgart, 1895 (E. Schweizerbart'sche Verlagshandlung—E. Koch).—In seven large plates the author has presented the forms with their several grades of symmetry belonging to each of the crystalline systems. A spherical projection accompanies each group and a brief explanatory text is added.

11. *The Mineral Industry, its Statistics, Technology, and Trade in the United States and other countries to the end of 1894* (Statistical Supplement of the Engineering and Mining Journal), vol. iii, edited by RICHARD P. ROTHWELL. 748 pp. 8vo. New York and London, 1895 (The Scientific Publishing Company).—This large volume is the third of the series and brings the summary of the state of mineral industries in this country and abroad down to the close of 1894. It has developed out of the series of annual statistical numbers of the *Engineering and Mining Journal* and gives evidence of the energy and enterprise of its editors. The editor-in-chief, R. P. Rothwell, has had the assistance of a large number of collaborators, sketches of about fifty of whom are given in the introduction. The result of their combined labors is this comprehensive volume, remarkable for its breadth of treatment as for the fullness of detail. Thus, in the case of each metal and other substances, not only is the amount mined given, but also the methods of mining and general metallurgical processes; also the methods of manufacture in the case of such products as alkalis, alum, sulphuric acid; both departments have numerous illustrations; finally a statement is given of the course of the market, as for copper, silver, etc. A vast amount of material of interest to different classes of people is thus brought together. The discussions are not limited to the products of the United States, but embrace also the world at large; for example, we note that a chapter of some length gives an account of the occurrence of phosphates in Tunis and Algeria by M. D. Levat.

12. *Field Columbian Museum:—Handbook and Catalogue of the Meteorite Collection*, by OLIVER C. FARRINGTON, Ph.D., Cur-

ator, Dept. of Geology. 65 pp. with plates. Chicago, 1895.—This Handbook, which forms No. 1, of volume I, of the Geological Series of publications by the Field Columbian Museum of Chicago, gives a catalogue of the remarkable collection of meteorites which the museum has already acquired. This includes 180 falls or finds aggregating in weight 4,721 pounds. Conspicuous among the rest are two specimens from Kiowa County, Kansas, weighing 466 and 345 pounds; a large mass with several hundred smaller fragments from Phillips County, Kansas, aggregating 1,184½ pounds; also two masses from Cañon Diablo, Arizona, weighing 1,013 and 256 pounds. Besides the catalogue proper, Mr. Farrington has given in the introduction an interesting popular summary of the subject, while a series of six excellent plates show the external appearance and structure of typical specimens of the different types.

III. Botany.

1. *Synoptical Flora of North America*, Vol. I.—Part 1, fascicle 1, Polypetalæ from the Ranunculaceæ to the Frankeniaceæ, by Asa Gray, LL.D., and Sereno Watson, Ph.D., continued and edited by B. L. Robinson, Ph.D., Curator of the Gray Herbarium of Harvard University. Issued Oct. 10, 1895. It is well-known that the Synoptical Flora was undertaken by the late Professor Gray as a revision of the early work issued by him and Dr. Torrey, in 1838 to 1843. For reasons which need not be now alluded to, Professor Gray decided to begin the publication of his revision with certain Gamopetalæ, and this work appeared in 1884, with a second issue in 1886. Other orders of Gamopetalæ and the Apetalæ were entrusted to his assiduous collaborator, the late Sereno Watson, while he himself turned back to those orders of Polypetalæ which stand first in linear sequence. In the investigation of these orders he was engaged when struck down by death. Dr. Watson then carried on the double task of proceeding with the later orders and revising some of the Polypetalæ which Professor Gray had left untouched in his review. With this work he was busy in his last days. After his death, in 1892, the fragmentary notes were committed to the present Curator of the Gray Herbarium, who has embodied in his revision the results of his extensive studies of old and of recent material. He promises a second fascicle at an early day: this will include the remaining Polypetalous orders as far as the Leguminosæ. He has the assurance of aid from various specialists who are to revise certain orders.

The two hundred pages which we have now before us constitute a composite publication in which the parts are well co-ordinated by skillful and exact editing. The contributions of each of the authors are properly credited, and the proportions are excellently kept. In nomenclature, Dr. Robinson has adhered to the practice adopted by his predecessors in the work, following, as he

says, in the matter of specific names, "the so-called Kew Rule, except where it leads to indefiniteness. The recent efforts to place botanical nomenclature upon a different basis have led to the hasty restoration in American botany of a considerable number of names, such as *Neckeria*, *Capnorchis*, *Beurera*, etc., which have been as quickly abandoned. The detailed citation of these names, and the numerous combinations to which they have led, forms no part of Dr. Gray's original plan, shown by the following words from his first preface: 'Compactness being essential, only the leading synonymy and most important references are given, and these briefly.' An effort has been made, however, to cite as synonyms such names as are at present indorsed by the Rochester and Madison Rules, and are included in the recently issued 'list of Pteridophyta and Spermaphyta growing without cultivation in northeastern North America, that is if such names do not coincide with those in the text."

The present fascicle will be welcomed as an earnest of the intention, so nearly frustrated by many untoward circumstances, of completing Professor Gray's monumental work. Even a cursory examination of the fascicle shows that the task has enlisted Dr. Robinson's hearty interest, and that he has brought to the task uncommon powers of analytical and descriptive treatment.

G. L. G.

2. *Another example of Chalazogamy.*—Dr. S. Nawaschin, of Kiew, Russia, in Botanisches Centralblatt, Sept. 25, 1895, gives an interesting account of his discovery that *Juglans regia* affords a distinct case to be added to those presented by Casuarineæ, Myricaceæ, etc., of impregnation not through the micropyle, but through the tissue at the chalazal contact. This special case has confirmed Dr. Nawaschin in the belief that the groups of plants which have this remarkable peculiarity constitute a transitional series between the Gymnosperms and the other Angiosperms.

G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *Meeting of the British Association.*—The annual meeting of the British Association for the Advancement of Science was held at Ipswich, county town of Suffolk, during the week beginning September 11th. The meeting was not a large one as regards numbers, but it was most successful with respect to the scientific interest and value of the papers presented. The President, Sir Douglas Galton, delivered the inaugural address, treating of the origin of the British Association, with a summary of the condition of the sciences at the time of its formation in 1831 with special reference to the progress made since then. This address is given in full in the copy of *Nature* for September 12, while the following issues give the other addresses, several of them of great interest, delivered before the several sections. A digest of the more important papers in the different depart-

ments is also given. The meeting for 1896 is to be held at Liverpool and the president elected is Sir Joseph Lister.

2. *On the origin of thunderstorms.*—A new theory of thunderstorms was advanced by Prof. Michie Smith in his paper before the British Association on Indian thunderstorms. His observations, made at Madras, showed that sheet-lightning occurs there every evening during several months of the year, always in the southwest and near the horizon. Lightning phenomena in the morning occur, on the other hand, in the northeast. The phenomena consist of actual discharges between two clouds, or two portions of the same cloud, and are not reflections of distant lightning; they take place in the upper portions of low-lying cumulus clouds. Professor Smith attributes them to the clouds formed in the regions of still air at the meeting of the land and sea breezes, and has observed in these regions the simultaneous rise of two close parallel clouds from the edge of the cumulus; such clouds are scarcely distinguishable except with oblique illumination, and it is within, or between, them that the discharges occur. The time of their formation depends on the hour at which the sea breeze sets in, being roughly three hours later. The land breeze being dry and dusty is negatively charged, while the sea breeze is known to carry a strong positive charge; equalization of the electrical states of the clouds formed out of these will, therefore, give rise to lightning. Professor Smith referred to the iridescence or nacreous appearance of the edges of the clouds when rapidly sinking, and considered this effect to be due to the dust left behind by them.

This paper gave rise to an interesting discussion, chiefly with reference to the origin of dust in clouds, and the source of their electricity. Mr. John Aitken pointed out that thunderstorms are most probably the effect, not the cause, of purifying the air. He gave instances of thunderstorms on several successive days, all of which left the air dusty and impure; eventually the air cleared, and no more thunder occurred. Professor Schuster alluded to the fact that twenty five theories of thunderstorms had been put forward in a dozen years, and in a single year five appeared. He attributed the positive charge of the sea breeze to the electrification of the air by the spray from the breaking waves; Lenard has shown that the spray of pure water gives a negative charge to the air, while that of salt water communicates a positive charge. He believed the dust of clouds to be acquired locally, except that at high altitudes, which we know to be carried long distances. A proof of this is to be found in the Himalayas, where certain valleys are dusty and others fairly free from dust, although all receive the wind from the Indian plains. His observations of nacreous clouds in England had led him to connect them rather with the ice particles of cirrus clouds than with dust. To this latter point Prof. Michie Smith replied that the nacreous appearance fits the edge of the cumulus so closely that he believes the two to be connected.—*Nature*, lii, 534.

3. *The uniformity of size of pages of Scientific Societies Publications.*—The committee appointed by the British Association, of which Professor S. P. Thompson was chairman, to consider the most desirable size of page for scientific publications, has made a report from which the following recommendations are taken. The importance of these will be readily understood:—

Standard octavo size.—Paper *demy*, the pages measuring $14^{cm} \times 22^{cm}$, or, when uncut, $5\frac{5}{8}$ in. $\times 8\frac{3}{4}$ in. The width, *c*, measured from the stitching to the edge of the printed matter, to be 12^{cm}, or $4\frac{3}{8}$ in., and the height, *d*, of the printed portion, including the running headline, to be 18^{cm}, or 7 in.

Limit of octavo size.—The paper page not to be less than $14^{cm} \times 21{\cdot}5^{cm}$, or $5\frac{1}{2}$ in. $\times 8\frac{1}{2}$ in., and the letterpress not to exceed the measurements $c = 12{\cdot}5^{cm}$, or $4\frac{7}{8}$ in, $d = 18{\cdot}5^{cm}$, or $7\frac{1}{4}$ in. Reprints and unbound numbers of journals to be issued with their edges uncut, or cut not more than $0{\cdot}25^{cm}$, or $\frac{1}{8}$ in., all round.

Standard quarto size.—Paper *demy*, the pages measuring, when uncut, $22^{cm} \times 28{\cdot}5^{cm}$, or $8\frac{3}{4}$ in. wide $\times 11\frac{1}{4}$ in. high. Reprints and unbound numbers of this size to be uncut, or cut $0{\cdot}25^{cm}$, or $\frac{1}{8}$ in. Measurements of letterpress to be $c = 18{\cdot}5^{cm}$, or $7\frac{1}{4}$ in, $d = 21{\cdot}5^{cm}$, or $8\frac{1}{2}$ in.

Limits of quarto size.—Paper pages not to measure less than $21{\cdot}5^{cm}$, or $8\frac{1}{2}$ in., wide $\times 28^{cm}$, or 11 in., high. Letterpress not to exceed the measurements $c = 19^{cm}$, or $7\frac{1}{2}$ in., $d = 23^{cm}$, or 9 in.

To avoid the mutilation of plates in binding the committee recommend that the dimensions of the illustrations should never exceed $13^{cm} \times 20^{cm}$, or $5\frac{1}{8}$ in. $\times 7\frac{3}{4}$ in., for octavo plates, and $21^{cm} \times 25^{cm}$, or $8\frac{1}{4}$ in. $\times 10$ in., for quarto, the width being measured from the back of the book. Where plates have to be folded, the fold should be $12{\cdot}5^{cm}$, or 5 in., from the stitching in octavo, and $20{\cdot}5^{cm}$, or $8\frac{1}{8}$ in., in quarto papers. Any folding plate should, when referred to elsewhere than in the opposite page of letterpress, have a blank space equal to the breadth of the paper page at the left hand, so that when open it can be referred to without closing the portion of the book being read that refers to it. This should be carried out even when the diagram or plate would not otherwise have to be folded, in order to reduce the trouble of reference.

Each article should begin a page. If possible it should begin a right-hand page. It is then possible to bind up any article with others on the same subject without having also to bind up the last half page of another paper.

4. *Map of the wooded area of Connecticut.*—Among the series of maps of Connecticut being prepared by the U. S. Geological Survey in coöperation with the State of Connecticut represented by its Commissioners, Wm. H. Brewer, James H. Chapin and Jonn W. Balou, the one expressing the areas covered by woods has appeared, published under date of 1893. The scale of the map is $\frac{1}{125000}$ with 100 foot contours.

5. *Principles and Practice of Agricultural Analysis*, vol. i, *Soils*, pp. 607, vol. ii, *Fertilizers*, pp. 332; by H. W. Wiley, Chemist of the U. S. Department of Agriculture.

Dr. Wiley's two volumes amply fulfill the promise of their title. The work which he proposes, and of which these two volumes are parts, is unique. There is certainly nothing in the English language which is at all similar in scope.

The preparation of the volume on soils is beset with more difficulty than any other part is likely to be, yet here we think the author has succeeded in treating the subject with good judgment and in a way that is very helpful and suggestive.

The origin and formation of soils and their physical properties are discussed with sufficient fullness for the purposes of the analyst, and the methods which have proved best suited to the physical and chemical examination of soils are accurately and minutely described. Necessarily methods of very different accuracy and value are described together, and no two authors would fully agree as to the material which should be received or rejected in a work like this. Some methods have been described, apparently for their historic interest, which are quite worthless for laboratory use.

We doubt whether the data given in part vii regarding bacteriological work will "enable the analyst to intelligently study the soil phenomena depending on these organisms" (the soil bacteria), "and to determine the extent and character of their biological and chemical functions," unless he is a bacteriologist of considerable experience, in which case the directions given would be quite superfluous.

The volume on fertilizers follows the same plan as the one on soils, and will be found of more immediate and practical value on account of the increasing demand in all parts of the country for fertilizer analysis and control. It is a laboratory guide in this department, which is invaluable to analysts who have this sort of work to do.

An admirable feature of both volumes, particularly acceptable to those who will use them as something more than a receipt book, is a full list of references to the authorities cited. E. H. J.

OBITUARY.

Professor Charles V. Riley, whose sudden death, due to an accident, was announced in our last number, was born in London, England, Sept. 18, 1843. He was educated first in England and later in France and Germany, and when hardly more than a boy came to the United States and settled on a farm in Illinois. His interest in natural history and especially in Entomology, which he had shown very early in life, was developed here, and still more later when, at the age of twenty-one, he became editor of the Entomological Department of an agricultural paper in Chicago. His work here brought him into notice, and in 1868, when only twenty-five, he was made entomologist to the State of Missouri, and from that time until 1877 he carried on under these auspices a series of important investigations upon the insects

injurious to agriculture, a field up to this time almost completely new. A very important part of this work was in connection with the locust, which did great harm throughout the West between the years 1873 and 1877. Of the nine annual reports which he published, several were largely devoted to this subject, and the excellence of this work led to his being made chief of the newly created United States Entomological Commission, an organization effected largely through his influence and established in 1877. In this he was associated with Dr. A. S. Packard and Prof. Cyrus Thomas. A number of exhaustive and highly valuable reports were published by this commission. Riley's investigations extended, especially in 1879 and 1880, to the cotton worm, and here also his labors proved of the highest service to the country.

In 1878 he had been made entomologist to the United States Department of Agriculture, but soon resigned the position to be re-appointed under more favorable conditions in 1881. In regard to his labors in building up the department of Entomology, Mr. L. O. Howard writes as follows in a sketch published in the Farmer's Magazine in 1890, from which are taken most of the facts of this notice:—

"The present efficient organization of the division of entomology was his own original conception, and he is responsible for its plan down to the smallest detail. It is unquestionably the foremost organization of its kind at present in existence. It has a small permanent corps of scientific workers, who have been trained under him, and who assist in the preparation and editing of reports, in the care of insects the life-histories of which are being studied, in the making of elaborate notes, in the mounting and arranging of specimens for permanent economic and classificatory collections, in making drawings for illustrations to the reports, and in the very large correspondence. The training of these assistants and their present efficiency and standing in the scientific world is only another instance of the thoroughness of Professor Riley's methods. Several of them have gone out from his office to accept important positions under the State governments, and thus the influence of his training has become widespread. Other entomologists are employed from time to time, and the clerical and other force is very efficiently arranged and systematically employed. A small number of permanent field agents are stationed in different parts of the country, working on the habits of insects in the field, and conducting experiments with remedies. . . ."

He also held the office of curator of the Department of Insects in the National Museum, and to this he presented his collection of one hundred and fifteen thousand mounted specimens of upwards of fifteen thousand species—a collection of the highest value to science. His researches included most of the insects especially injurious to American agriculture, and also the phylloxera. His work in connection with the latter led to his receiving, in 1873, a gold medal from the French government." That

he was always an indefatigable worker will be apparent from what has been said of the work which he accomplished, but it would be made more apparent by an enumeration of the long list of his writings. The untimely ending of a career so full of active, useful work, is a great loss to science and his country. We close this notice with another quotation from the same source, which is interesting as giving an insight into one side of his character:

"One other trait which we have not mentioned is his persistency in overcoming obstacles. Nothing daunts him, and the more difficult an end is to attain, so much the more energy and perseverance does he put forth in its pursuit. A recent instance of this quality we may cite: The Fluted Scale (*Icerya Purchasi* Maskill) has done great injury to citrus fruit in Southern California of late years. Ascertaining that it is kept in check by natural enemies in its native home, Australia, Dr. Riley foresaw the importance of endeavoring to introduce these enemies. Not only did Congress refuse to appropriate money for the purpose, but it refused to do away with a clause in the appropriation bill restricting all expenditures to the United States. In this state of affairs most men would have given up the fight; but Dr. Riley, after great trouble, succeeded in accomplishing his end by inducing the Secretary of State to allow the sending of two assistants on the Melbourne Exposition Commission, and through their labors the desired result was reached. Hundreds of specimens of an Australian lady-bird (*Vedalia cardinalis*) were introduced into California, and the dreaded pest is now being speedily reduced to absolute harmlessness. Professor W. A. Henry of Wisconsin, in a recently published article, says of this matter, in speaking of the enthusiasm of the people of California over the result of this importation: 'Without doubt it is the best stroke ever made by the Agricultural Department at Washington.'"

M. Louis Pasteur, whose researches in chemistry and bacteriology have proved of such incalculable benefit to humanity, died on September 28, at the age of sixty-three. It may be questioned whether it has ever been the privilege of any other scientist to accomplish so much for the welfare of his fellow men and the alleviation of their sufferings, as he did through his own labors and those which he inspired.

Eli Whitney Blake, Professor of Physics in Brown University, died on October 1st, at the age of fifty-nine.

Dr. Albert E. Foote, the indefatigable mineral collector, whose active labors through many years have contributed largely to the development of a widespread interest in mineralogy throughout the country, died at Atlanta, Georgia, on the 10th of October, in his 49th year. He had suffered long from ill health, but notwithstanding physical disability he carried on his work with unceasing energy and enterprise up to the very last.

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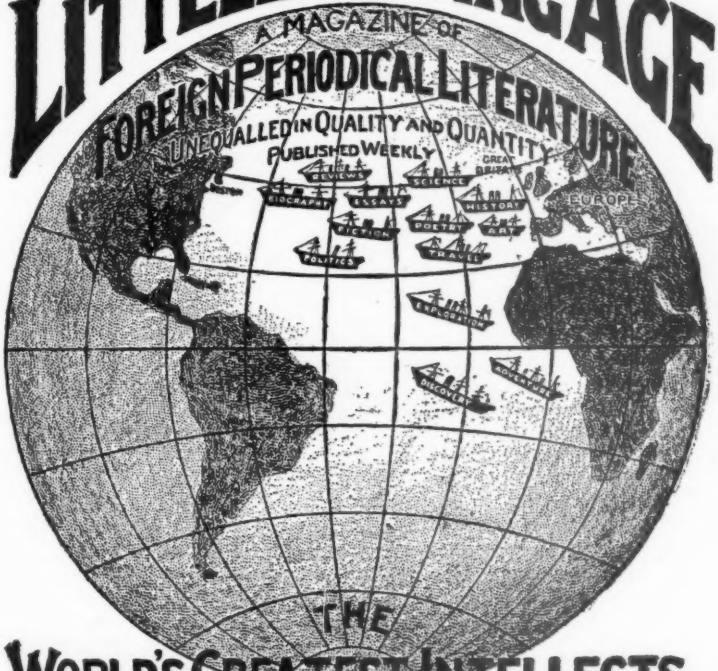

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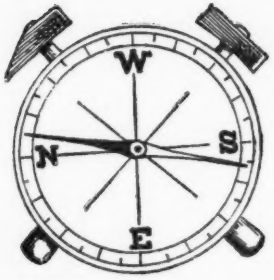
MINERALS.



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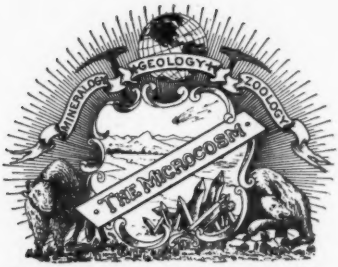

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CONTENTS.

	Page
ART. XXXVII.—Wave Length of the D_3 Helium Line; by A. DEF. PALMER, JR.	357
XXXVIII.—Additional Notes on Argon and Helium; by E. A. HILL	359
XXXIX.—Recent Progress in Optics; by W. LECONTE STEVENS. Part II.	377
XL.—Effect of the Mutual Replacement of Manganese and Iron on the Optical Properties of Lithiophilite and Triphylite; by S. L. PENFIELD and J. H. PRATT	387
XLI.—Ammonium-Cuprous Double Halogen Salts; by H. L. WELLS and E. B. HURLBURT	390
XLII.—Some Phonolitic Rocks from Montana; by L. V. PIRSSON	394
XLIII.—Reduction of Selenic Acid by Hydrochloric Acid; by F. A. GOOCH and P. S. EVANS, JR.	400
XLIV.—Reduction of Selenic Acid by Potassium Bromide in Acid Solution; by F. A. GOOCH and W. S. SCOVILLE	402
XLV.—Reptilia of the Baptanodon Beds; by O. C. MARSH	405
XLVI.—Restoration of Some European Dinosaurs, with Suggestions as to their Place among the *Reptilia*; by O. C. MARSH. (With Plates V–VIII.)	407

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Refractivity and viscosity of Argon and Helium, LORD RAYLEIGH: Compound nature of the gas from Cleveite, C. RUNGE and F. PASCHEN, 413.—Specific refraction of Argon, 416.—Color Photography, O. WIENER, 417.—Electric Aureole: and Stratifications in the Electric arc and in discharges in rarified gases, LEHMANN: Magnetism of Asbestos, BLEEKRODE: Electric refraction of Liquids, P. DRUDE: Double refraction of electric waves in ice, V. BIERNACKI, 418.—Double refraction of electric waves, P. LEBEDEW, 419.

Geology and Mineralogy—Temperature Variation of the Thermal Conductivity of Rocks, LORD KELVIN and J. R. E. MURRAY, 419.—United States Geological Survey: 14th Annual Report for 1892–93, 423.—Gold fields of the Southern Appalachians, G. F. BECKER: Columnar sandstone, J. M. CURRAN: Petrology for Students, A. HARKER, 425.—Introduction to the study of Rocks, L. FLETCHER: Calaverite from Cripple Creek, Col., W. F. HILLEBRAND: Minerals from New South Wales, A. LIVERSIDGE, 426.—Contribution to the Mineralogy of Wisconsin, W. H. HOBBS: Tabellarische Uebersicht der einfachen Formen der 32 krystallographischen Symmetriegruppen, Dr. E. A. WÜLFING: Mineral Industry, its Statistics, Technology, and Trade in the United States and other countries to the end of 1894: Field Columbian Museum, Handbook and Catalogue of the Meteorite Collection, O. C. FARRINGTON, 427.

Botany—Synoptical Flora of North America, vol. I, A. GRAY, S. WATSON, B. L. ROBINSON, 428.—Another example of Chalazogamy, DR. S. NAWASCHIN, 429.

Miscellaneous Scientific Intelligence—Meeting of the British Association, 429.—Origin of Thunderstorms, 430.—Uniformity of size of pages of Scientific Societies Publications: Map of the wooded area of Connecticut: Principles and Practice of Agricultural Analysis, H. W. WILEY, 431.

Obituary—Professor CHARLES V. RILEY, 432.—M. LOUIS PASTEUR: Professor ELI WHITNEY BLAKE: Dr. ALBERT E. FOOTE, 434.

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